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INDEX.

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LIST OF CONTRIBUTORS.

INDEX TO SUBJECT-MATTER.

A Manual of the Steam-Engine.

BY

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Director of Sibley College, Cornell University; Formerly of the U. S. N. Engineers; Past President Am. Society Mech. Engrs.; Author of "A History of the Steam-Engine," "Manual of Steam-Boilers," "Materials of Engineering," Etc., Etc., Etc.

Part I. STRUCTURE AND THEORY.—History of the Steam-Engine. Structure of Modern Engines. Philosophy of the Steam-Engine. Thermo-dynamics of Gases and Vapors. Theory of the Steam-Engine. Compounding; Jacketing; Superheating. Efficiencies of the Steam-Engine.

Part II. DESIGN, CONSTRUCTION, OPERATION. Design of the Steam-Engine. Valves and Valve Motions. Regulation; Governors; Fly Wheels; Inertia Effects. Construction and Erection. Operation; Care and Management. Engine and Boiler Trials. Specifications and Contracts. Finance; Cost and Estimates.

Each part 8vo. 900 pages, $7.50; or two parts together, $12.00.

Published by J. Wiley & Sons, 53 E. 10th St., New York City.

Those who desire an edition in French, can obtain it of Baudry et Cie, Rue des Saints-Pères 15, Paris.

A MANUAL OF THE STEAM ENGINE is here presented to the student and practitioner in steam engineering, for the first time, as is believed, which is a complete treatise upon the steam-engine of the present day, from both theoretical and the practical stand-points. Earlier treatises have usually either given simply the thermo-dynamic theory of the engine, the pure theory of an ideal, non-existent, machine, or working drawings, mainly, without complete scientific discussion. In this work we have a complete, though condensed, and systematic account of the rise and progress, and of the present forms, of the standard types of engine; a summary of the scientific principles finding application in its design and construction; an outline of the growth of the science of thermo-dynamics and of the general physical, as well as the merely thermo-dynamic, theory of heat-engines; the theory of the real, as distinguished from the ideal engine; accounts of the various methods of promoting their economic value,

and an outline of the theory of their efficiencies. In the second of these volumes, are considered the design, the construction, and the operation of the engine; care and preservation when off duty; methods of determining the efficiency and economy of the engine and boiler; forms of contract; and specifications insuring correct design and good construction. A chapter on the finance of the engine and its operation concludes this part.

Very much of this work is entirely new. The history of the engine is brought up to date and is treated in a philosophical manner; the same is true of the account given by this author of existing constructions, including the "high-speed" and the "multiple-cylinder" engines. The historical account of the development of the modern and complete theory of the real, as well as of the ideal, engine is introduced for the first time into a treatise on the modern steam-engine and thus brings the subject up to date; showing clearly how engineers and men of science have come to see precisely what are the exact forms of the wastes of energy in the steam-engine and other motors deriving their power from heat energy. It exhibits as clearly the directions in which further improvement is to be sought, and the secrets of the high efficiency of the best modern engines. The thermo-dynamics of working substances in heat engines is thought to have been here rendered exceptionally clear by the combination of the methods of treatment of the Continental with those of British writers on the subject; while the distinction between the purely thermo-dynamic, and the actual case, in which thermal, as distinguished from thermo-dynamic, action is observed, is carefully brought out. The theory given is that of the "real engine," as actually constructed and operated, and as affected by not only thermo-dynamic but all other wastes. The best work of all earlier writers is here made available to the reader.

On the whole: the publishers are convinced that purchasers of this work will find it full of new and valuable matter, combining all the information that should constitute such a treatise as this is, by its title, indicated to be. The long and varied experience of its author, including many years of practical experience in the design and construction, and in the actual management of steam machinery, as well as his equally extended experience as a teacher of the theory of engineering, and his great opportunities for research, and in all forms of practical investigation, should be ample assurance that the work will have peculiar value to theorist and practitioner alike. The fact that it has already been found useful in the offices of the leading engineers of the time, at home, and in its translation abroad, and in the highest classes of

technical schools giving graduate instruction in engineering, may be taken as fully confirming our estimate of its probably successful occupation of the position of a standard treatise on the theory and the practice of steam engineering. The appended extracts, from reviews by leading periodicals generally accepted as authoritative, will show how promptly and completely the MANUAL has been accepted and welcomed by members of the profession in Great Britain and on the continent of Europe as well as in the United States.

REVIEWS.

We know of no other work on the steam engine which fills the field which this work attempts, and it therefore will prove a valuable addition to any steam engineer's library. It differs from other treatises by giving, in addition to the thermo-dynamic treatment of the ideal steam-engine, with which the existing treatises are filled *ad nauseam*, a similar treatise of the *real* engine.—*Engineering and Mining Journal, New York City.*

The author's experience during twenty-five years of uninterrupted employment as a specialist in technical college work, and of thirty years of practical experience and work in the design, the construction, the management, and the scientific investigation of the principles of the steam-engine, and his careful observation of its gradual development, qualify him peculiarly well for the undertaking and successful completion of a work of this kind, which will undoubtedly be considered a standard work by the professional engineer and student.—*American Machinist, New York City.*

The author is so well known as one of the highest and most reliable authories upon the steam-engine that one unconsciously looks for the best from his pen, and we are not disappointed. The book is in the style familiar to readers of other works by this author, is clear at all times and concise, yet not at the sacrifice of understanding.—*Journal of Commerce, Boston.*

This work is an epitome of the steam-engine in every sense, and we unqualifiedly recommend it to our readers engaged in the practical handling or management of steam ; to all such we would say "get it" as a standard volume of educational excellence.—*Marine Record, Cleveland.*

The present volume is in no wise inferior to the author's previous works and is in many respects superior ; or rather it is a complement to the work he has hitherto done in the same direetion ; a boiling down, as it were, of the wide knowledge gained by years of observation and practical experience in the shop and class-room. Starting with an exhaustive history of the steam-engine, Prof. Thurston proceeds to show it as it is built to-day, and then to give the theoretical reason why it is so built.—*Weekly Stationary Engineer, Chicago.*

The first part of this work we noticed some time ago. Any work from the pen of Prof. Thurston must be treasured, and although this volume is intended as a text-book for very advanced students, it must prove invaluable to the practicing engineer. The work must be seen and studied to be appreciated. We can but say that the subject has been handled ably and exhaustively, and by as competent a man as there is in the country to speak on the subjects of which he treats. The book is beautifully printed and illustrated.—*American Manufacturer and Iron World, Pittsburg.*

Prof. Thurston is a recognized authority on this subject all over the world, and no one is better fitted for writing a manual of the steam-engine than he is. He has written several important technical books before, but nothing equal to this one. It is a standard work of study and reference, and will be in the library of every mechanical engineer in the country.—*Scientific and Mining Press, San Francisco.*

All that is necessary to say of this second volume of Professor Thurston's great work is that it upholds fully the promises of the first volume. Design, regulation of speed, construction and erection, operation, care and management, engine and boiler trials, specifications and contracts, and finance of steam engineering are the topics more particularly covered. Its size, style and author are enough to make it a *sine qua non* for every engineer who wishes to keep abreast of the present day.—*Scientific American, New York City.*

No such thorough treatise on the steam-engine has ever before been issued. —*Marine Journal, New York City.*

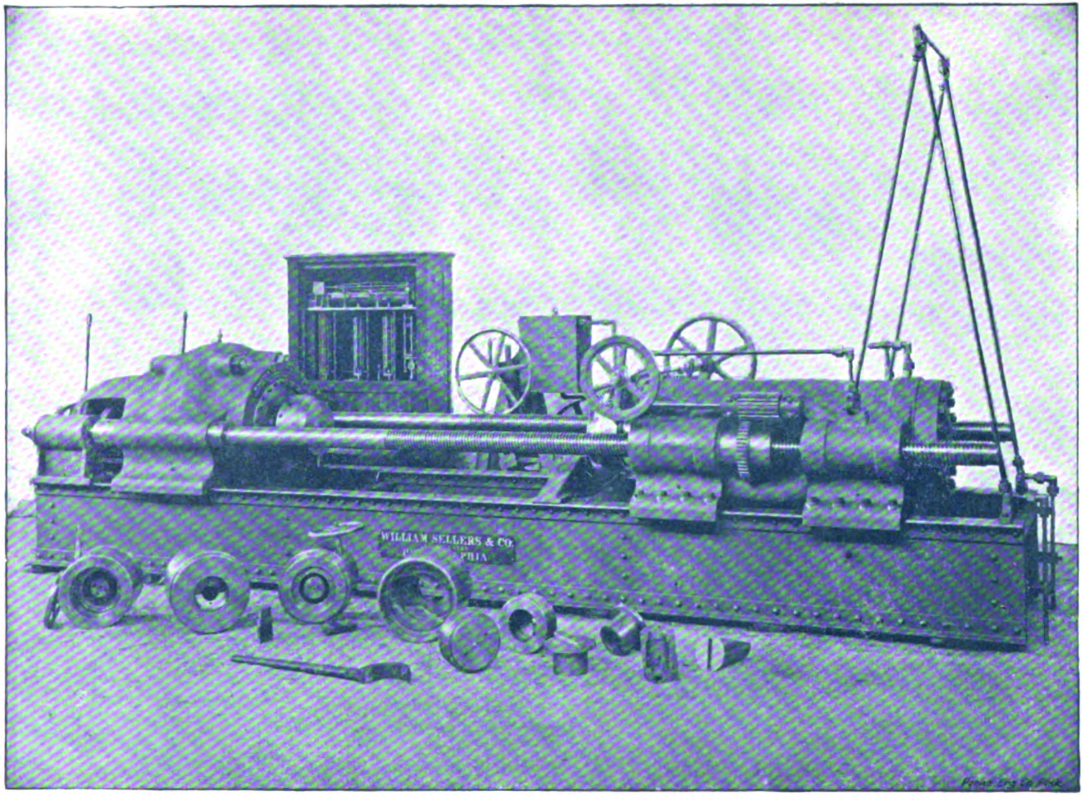
While Professor Thurston, on the title page, states that the work is intended for engineers and technical schools, it can be read with profit by any one interested in steam engines, as the mathematical parts are not at all essential to a fairly complete mastery of its contents, although there are some portions, as for instance those relating to inertia effects, which are rather beyond the comprehension of one not well versed in mathematics.—*Journal Franklin Institute, Philadelphia.*

In this the most recent important treatise on the steam engine, Professor Thurston has produced a work which deserves to long occupy a foremost place in this branch of engineering literature. The author has from time to time published contributions upon various subjects connected with the steam engine, which have invariably been distinguished by originality of treatment and perspicuity. The work is written in the Professor's usually pleasant and interesting style, and fully sustains his reputation as an author. A word cf praise is due to the publishers, who have produced the work in their customary high class manner.—*Mechanical World, Manchester, England.*

The hope with which we concluded the notice of the first volume of this work has been realized, and our expectations in regard to the importance of the second have not been disappointed. The practical aim has been fully carried out, and we find in the book all that it is necessary to know about the designing, construction and operation of engines; about the choice of the type, the materials and the lubricants; about engine and boiler trials; about contracts. The volume, which closes with an original and important study of the financial problem involved in the construction of steam engines, is necessary to constructors, useful to students, and constitutes a collection of matter independent of the first part, in which the theory is developed. *The publication is a success worthy of all praise.*—Prof. FRANCESCO SINIGAGLIA, *Bollettino del Collegio degli Ingegneri ed Architetti, Naples.*

In this important work the history of the steam engine, its theory, practice and experimental working are set before us. The theory of the steam engine is well treated and in an interesting manner. The subject of cylinder condensation is treated at great length. The question of friction in engines is carefully handled, etc., etc. Taken as a whole, these volumes form a valuable work of reference for steam-engine students and engineers.—*Engineering, London, England.*

The volume extends to about 960 pages (including the introductory matter), and forms, with the first part, the most valuable and important addition to the literature of the steam engine that has been made of recent years. The two volumes, which are beautifully printed in clear, readable type, are splendid specimens of the printer's art; the illustrations are numerous in both books; the binding is excellent; and the whole get up of the work reflects the highest credit on the publishers, who, we anticipate, will have a large demand for the manual. The work is one which we have every confidence in recommending to our engineering friends, especially to all those who desire to acquire the requisite knowledge to enable them to reach the higher grades of their profession, and which can only be attained by a thorough and systematic study of such manuals as the one under notice.—*The Steamship, Leith, Scotland.*



THE EMERY TESTING MACHINE.

SEE PAGE 19.

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IN CORNELL UNIVERSITY

"The leading object shall be, without excluding other scientific and classical studies, and including military tactics, to teach such branches of learning as are related to Agriculture and the Mechanic Arts, in such manner as the legislatures of the States may respectively prescribe, in order to promote the liberal and practical education of Industrial Classes in the several pursuits and professions in life."—[An act donating public lands to the several States and Territories which may provide Colleges for the benefit of Agriculture and the Mechanic Arts, July 6, 1862.]

TECHNICAL EDUCATION IN THE UNITED STATES.*

The writer of the above-mentioned article, in his treatment of the subject, emphasizes and brings out very strongly the contrast that exists between the condition of technical education in this country to-day, and what it is, and has been for many years, in the European countries, and shows the wonderful advantages to be derived from the system there in vogue. He points out the need in this country of state supervision and aid in developing a great system of engineering schools, that would allow every man and woman to have the opportunity to so educate himself or herself, as to get the maximum good out of mind and hands in directing the forces of nature and utilizing the natural ability and skill at his or her command. He traces the development of engineering schools in this country from the time of the establishment of the first, the U. S. Military Academy at West Point, N. Y., in 1802, down to the present time, showing the effect which the establishment of these schools has had upon the advancement of the nation. It has educated the people in the line of practical industry, and by so doing, has materially increased the prosperity of the country. If we had schools in every state, city, and town, offering instruction in the practical arts such as carpentry, black-

*** From a paper presented, by Dr. R. H. Thurston, before the Mechanical section of the World's Engineering Congress, held in Chicago during the month of July, 1893.**

smithing, stone-cutting, weaving, and the like, it would prove a blessing to the country, the advantages of which can hardly be over-estimated. The manufacturer can afford to pay his employees higher wages when the latter, owing to their possession of knowledge and skill, can do more work in a day, than if they were uneducated; and higher wages to the laboring classes allows them to secure the advantages of intellectual and even moral advancement, otherwise denied them, resulting in raising the standard of civilization of the whole people. The higher institutions of learning, the technical and engineering colleges, in which the scientific development of the constructing professions is aimed at, would enable their graduates, having at their command a force of trained artisans, to contrive methods of using the forces of nature and to invent and design new and useful appliances for the advancement of their profession. Another important function of these higher schools is that of supplying competent and efficient instructors for themselves and for the lower schools, men who can add to a scientific and theoretic knowledge of the subjects they teach, practical experience in their various lines. Professor Thurston says:

A general system of education of the people, aiming at their preparation for the intelligent performance of their duties, and for success in their vocations, must comprehend the following elements of a complete system specially adapted to their purposes, apart from the system of education for education's sake, which was formerly considered the only education to be offered, and that only to the well-to-do among the citizens of the nation:

(1) A common school system of general education, which shall give all young children tuition in the three studies which are the foundation of all education, and which shall be administered under compulsory law, as now generally adopted by the best educated nations and states on both sides of the Atlantic.

(2) A system of special adaption of this primary instruction to the needs of children who are to become skilled artisans, or who are to become unskilled laborers, in departments which offer opportunities for their advancement, when their intelligence and skill prove their fitness for such promotion, to the position of skilled artisans. Such a system would lead to the adoption of reading, writing, and spelling books in which the terms peculiar to the trades, the methods of operation, and the technics of the industrial arts should be given prominence, to the exclusion, if necessary, of words, phrases, and reading matter of less essential importance to them.

(3) A system of trade schools, in which general and special instruction should be given to pupils preparing to enter the several leading industries, and in which the principles underlying each industry, as well as the actual and essential manipulations, should be illustrated and taught by practical exercises until the pupil is given a good knowledge of them, and more skill in conducting them. The series should include schools of carpentry, stone-cutting, blacksmithing, weaving schools, schools of bleaching and dyeing, schools of agriculture, etc., etc.

(4) At least one polytechnic school, in which the sciences should be taught and their application in the arts indicated and illustrated by laboratory work. In this school, the aim should be to give a certain number of students a thoroughly scientific education and training, preparing them to make use of all new discoveries and inventions in science and art, and thus to keep themselves in the front rank.

(5) A system of direct encouragement of existing established industries by every legal and proper means, as by the encouragement of improvement in our systems of transportation, the relief of important undeveloped industries from State and municipal taxes, and even, in exceptional cases, by subsidy. It is evident that such methods of encouragement must be adopted very circumspectly and with exceedingly great caution, lest serious abuses arise.

(6) A system of general supervision of the industries of the State by properly constituted departments of the State government. This system should comprehend, perhaps, a Bureau of Statistics, authorized, under the law creating it, to collect statistics and information relating to all departments of industry established, or capable of being established, in the State, and to publish such information and statistics in circulars for general distribution, and in a report to be made to the State legislature, annually, with the governor's message.

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"Aside from the improved value of the engineering college as a means of technical and professional education and training, this attainment of the end, so long held in view, has this most important result: that it is now possible to clearly show to intending aspirants for degrees that, since it must be a professional school, there cannot be expected of it any considerable portion of that literary training which constitutes general education, and that this should be sought, as in the case of the study of

law, before entering the professional school. It has often happened that parents, as well as young men proposing to study for a profession, have made the serious and almost fatal mistake of assuming the possibility of securing at the same time a good general education, in English and scientific branches, at least, and a professional training, and that it is practicable to secure either an education in the professional school or a professional training in a semi-educational institution. This, experience proves, in engineering as in law, to be entirely impracticable. The small amount of general education given in any of the professional schools has little value for its purpose while simply crippling to a more serious extent the work for which the school is especially fitted and established. The education—and as complete and as broad an education as the means of the student will permit—should be first secured and made a sound and ample foundation for his life-work ; *then* the young man should take up his professional work, well prepared to appreciate it, mature, intelligent, earnest, and discriminating. The professional man, whether physician, engineer, lawyer, or divine, should give his time and thought, in early years, to the securing of the best possible education in the best possible way *first*, and, that done and well done, should next take up a professional course. The whole strength and all attention should be given first to one, then to the other, to secure highest results in either field.''*

European nations have been for many years, for a century at least, steadily, systematically, and intelligently carrying out the policy above outlined, and the only way in which to compete with them is evidently to adopt a similar policy, with even greater care and with, if possible, more effective methods. Technical and trade education have for so many years been a part of the European systems of aiding manufactures that we may expect it to require many years to equal, much more to overtake them in the race. The effect has long since been felt in the importation of skilled artisans and engineers from those countries to do work demanding the peculiar expertness coming of such scientific training. We have taken up our work in this direction none too early.

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It is difficult to realize the rate at which foreign nations are

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*Sibley College Reports 1892.

advancing in this direction, and how rapidly our own country is being distanced. It will demand the most earnest thought and the most energetic action on the part of those entrusted with the work of developing our educational system to prevent a very serious, if not disastrous, competition from abroad within probably the next generation. It is fortunate that the change has progressed in our own country even so far as it now has, and that its continued progress is assured.

. . . .

The new education, which is yet the old, is simply that advance in the application of these never-denied and long-admitted principles of polity and of public policy which has come to be seen to be demanded as a consequence of the progress of the age in invention, in the arts, and in our systems of industry. Reading, writing, and arithmetic were once the all-sufficient education of every class engaged in industrial pursuits. To-day a college education is insufficient to meet all the demands of some of the professions; and special schools are established in every country and in almost every city. A few years ago there were but three professions, and but three kinds of professional schools; to-day there are many both of the professions and of the schools. The old education was mainly gymnastic; the modern is both gymnastic and immediately useful in the vocations of daily life. The old university was a home for those who were called by Isaac Walton "cloisteral men of great learning"; the university of to-day is a workshop of all the arts and sciences as well as of the literatures. It is the product of a growth, not of a new planting, however, and we may reasonably hope for indefinite future improvement, and more and more splendid fruitage with the coming years.

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THE IDEAL EDUCATION would be such as should fit the citizen for successful pursuit of every desirable object in life, while enabling him to secure the capital needed for its complete attainment and thorough enjoyment. It would begin with the primary instruction demanded as preparatory to the studies of its later periods. The primary education would be followed by so much of secondary education, in the sense in which that term is now generally used, as should give to the youth the essential elements of a truly liberal education, such as should prepare him to continually advance into the unlimited fields of human knowledge; to gain from day to day, through all his after life, more knowledge

and higher learning in every division of science, literature, and art; to enter upon the philosophical study of history, the comprehension of comparative philology, of the development of literatures; of the seductive and wonderful problems of mathematics; of the no less wonderful principles and strangely beautiful phenomena of the physical sciences; the still more marvellous laws and operations of nature, as illustrated in the living creation; and, more than all, to obtain some comprehension of the moral and the intellectual, sufficient, perhaps, to gain a glimpse of that great spiritual world of which the grandest minds and the loftiest imaginations which the human race has yet produced have never yet been able to grasp more than the most infinitesimal portion. A truly liberal education (and by this I mean vastly more than a strictly classical education) fits man to walk with his Creator in every field, spiritual, intellectual, physical, which the creature's faculties are given him to explore.

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Progress in the United States, although so early begun, in this direction, has gone neither so far nor so thoroughly into the newer fields as every citizen should wish; but it has nevertheless been, of late, very considerable, and its movement is to-day an accelerating one, promising, in the near future, to become as rapid as is desirable or is likely to prove wholesome. "There is no finer vista of political progress in the developement of the American Republic than that afforded by the changing views of education sustained by the people and constantly modified by marked political tendencies. There is no better example of the influence of politics upon culture and learning than that presented by a historical perspective of the ideas which have developed our great educational system."* The movement in favor of a national University which would be what President Schurman would call "A People's University" was perhaps the first though an as yet unfruitful one in the direction of the organization of the system now gradually taking form as the new illustration of Milton's "perfect education." The ideal form of this "capsheaf" of the educational pyramid is sufficiently well indicated by the writers from whom I have quoted; but perhaps most perfectly by President Schurman, thus:

"A people's university, if it is true to the spirit of the age, must hold all subjects equally reputable, and provide instruction

* Professor Blackmar.

in all alike. Least of all can it afford to omit those industrial arts which lie at the foundation of our modern life. But, with them, it must include every interest of the people which admits of scientific treatment. The masses and the classes must both be represented. Or, rather, such a university can recognize no such distinction ; for the objects of every occupation must be esteemed equally significant. The analysis of soils is as important as the analysis of literature. The steam-engine is as sacred as Greek. Philosophy is not more venerable than road-making. A house is as rational as the geometry that it embodies. We must no longer dream that the little section of knowledge that we cultivate is the holy of holies. Every atom of the universe is equally worthy of regard.

> " 'All are but parts of one stupendous whole,
> Whose body nature is, and God the soul.'

". . . In God's universe there is nothing common or unclean, and whatever is known about it must have a place in the curriculum of a people's university."

As the same able writer and eloquent speaker has asserted, the curriculum must be as varied as are the wants of the people. The day of the people has arrived, and "if, since the foundation of Salerno, universities have been dedicated to the investigation of nature with a view to providing a remedy for human diseases, they now assuredly need a fuller consecration to the same service for the additional purpose of rendering more available to our helpless race those natural powers and operations by which the works of man are affected and the life of man sustained."

. . . .

A complete system of technical science instruction and of industrial education has been incorporated into the continental educational structure, which places before every child in the land the opportunity of giving such time, as the social position and pecuniary circumstances of its parents enable them to allow it, to devote to the study of just those branches which are to it of most vital importance, and to acquire a systematic knowledge of the pursuit which surrounding conditions or its own predilections may lead it to follow through life, and to attain as thorough a knowledge and as high a degree of skill as that time, most efficiently disposed, can possibly be made to give him. There is here no waste of the few months or years of, to him, most precious time which the son or the daughter of the humblest

artisan can spare for the acquisition of a limited education. Every moment is made to yield the most that can be made by its disposition in the most thoughtfully devised way that the most accomplished artisans and the most learned scholars, mutually advising each other, can suggest.

One day in such schools as those here described is of more value to the youthful worker than a week in the older schools, or than a month in the workshop or the mill. Thus, while the fact is recognized that a general and a liberal education is desirable for every citizen, the no less undeniable fact is also recognized that few citizens can give the time to or afford the expense of a symmetrical general course, and that the interests of the individual and of the state unite in dictating the provision of such systems and means of industrial education and training as are now actually provided.

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In Europe, the custom has come to be almost universal to isolate the technical schools from the classical institutions and older universities. This has come about partly through the conviction that better work will be done by each class of college if allowed to work unhampered by the different methods and even the conflicting views, feelings, and traditions of the other ; partly, perhaps, in consequence of their different foundations. Many able men favor both systems, and the amalgamation of the university and the technical school is likely to be given faithful trial here and there on the continent, and in Great Britain perhaps still more completely ; but they are to-day practically separately administered in nearly all cases. The view of the relative importance of manual and of gymnastic training of the mind which prevails generally in Europe is that, in the higher schools of technology at least, the training of the hands constitutes no part of the essential education of the engineer even, and that these schools should confine themselves entirely to the instruction of the student in the principles of his art, avoiding the practice, so far as it involves the use of the hands. It is perhaps a consequence of this belief and practice that the states of Europe have been, for years past, flooded with well-educated, untrained young aspirants for entrance into this vocation who not only have been unable to find employment, but who have, in many instances, been informed by employers that they are not wanted. It is the man who suitably unites theoretical and practical knowledge and

training who is wanted and who best succeeds, in Germany no less than in the United States.

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What foreign countries are doing in individual instances for the higher education may be understood from the statement of President Adams, that "one of the minor universities of Great Britain has recently completed a collegiate building at a cost of £500,000," and the Prussian Polytechnicum, at Charlottenburg, Berlin, represents four millions of dollars. The Zurich Polytechnic School has spent a quarter of a million of dollars on its chemical laboratory, and nearly as much in building its physical laboratory. "The little kingdom of Saxony, only half as large as Vermont, annually gives from its public treasury $400,000 to its university, although the institution itself has great wealth and the professors are supported mainly by fees from students." It is thus that European nations are carrying into effect a principle which was incorporated into the ordinance of 1787 by which the United States applied its great surplus to this purpose: "Religion, morality, and knowledge being necessary to good government and the happiness of mankind, schools and the means of education shall forever be encouraged."

. . . .

The Land Grant Colleges of the United States—of the several States, rather—are the product of one of the grandest examples of statesmanlike legislation that the world has yet seen; one second in importance and fruitfulness to no act of legislation subsequent to the promulgation of the Constitution of the United States. Like all great enterprises having for their purpose the benefit of the people by legislative enactment, this failed of complete success through the indifference, the folly, and the absolute stupidity of many of those public servants to whom its operation was entrusted; it has, nevertheless, produced uncalculable good, both directly, in the foundation and partial support of technical education, and also partly, and very probably to a vastly greater extent, through its influence upon the States, inducing them to take up and carry on the work from the point at which the General Government left it. It is largely to this legislation that the foundation of the now numerous State universities is due, and the organization of the systems of State education which now more or less completely cover the whole field from primary schools to universities in the large proportion of our States, illustrating the scheme of a complete system of State education to which ref-

erence was made and of which the outline was given in the earlier part of this discussion, and more satisfactorily than anywhere else outside of Germany.

. . . .

Three-fourths of the States now have either State universities or public institutions that will soon come to rightfully claim that title. In 1885 the total endowments amounted to $50,000,000, and their unproductive property to about $45,000,000. Nearly 70,000 students were in attendance, paying an average of about $25 for tuition. Since the passage of the Morrill Land Grant Act in 1862 there has been a steady development of the system of State universities as the apex of the educational pyramid, and, also, in the lower planes, of more general and effective support of primary and secondary education with more and more thorough and perfect incorporation into the whole educational structure of the State.

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The importance of State universities and the value of institutions which tender free higher education, and even in some instances professional education, to the poorest of the citizens of the commonwealth, need not be discussed at length. The number of young men—and of young women indeed—now seeking such education is large and daily increasing; but there are comparatively few who can find means of self-support during the long period of primary and secondary education and preparation, to say nothing of meeting costs of instruction; and, although they are often willing—compelled, in fact—to live with a frugality approaching actual suffering, occasionally even passing the line, many fail to reach their goal. Every dollar which can be saved them in this long and arduous race is an aid to the State; for it enables the community to profit by talent, strength of character, mental discipline, possessed by this class to an extent unapproached by any other body of young people in the community. The writer has known of young men living on sixty cents a week, and of many supporting themselves while in college on a dollar and a dollar and a quarter a week, depriving themselves of all but absolute necessities, of necessities even, to secure a college or a professional education. It is of such stuff as this that the most desirable citizens are constituted. It is by the facilitating of the admission of a larger proportion of this class to the constructive and to the so-called learned professions that the State universities of this country will undoubtedly do most to promote the best interests of the whole people.

The aid of the State is essential to the complete and permanent success of the higher education in any community. This proposition becomes sufficiently evident when it is considered that it constitutes the apex of the pyramid, must be firmly and intimately based upon and connected with the secondary education of the community, and that in turn must be similarly united with and built up on the primary education which is at the base of the whole edifice. Further, that constant and effective and reliable support which higher education, even more than the lower grades, must be assured, can only be furnished by the state. The colleges and universities which depend upon private endowments and support are not only always in need through the operations of natural growth, but, although often richly endowed, invariably receive such additional aid as they thus obtain at irregular and uncertain periods, and usually absolutely irrespective of their crises of need. That essential element of permanent and highest success—regular, ample, and certain income—can only be insured by the state and through a fixed and positive system of legal appropriation. Every great and famous university in Europe stands upon such a basis of state aid; every college and university in the United States, having no such backing, is in constant difficulty from the entire independence of its income and its necessary expenditures. This is the case even with institutions like Cornell University, for example, with its millions invested. Not only do its opportunities widen faster than its income increases, but its varying income has absolutely no even approximate relation to its needs. The larger universities of this class, which are mainly in the east, are always needy, and the wealthier they are the more needy are they; as it is invariably the fact that they expand as rapidly as physically possible, and endowments provided, however largely, find even more prompt and more effective application than in the smaller colleges. They afford the largest and most efficient opportunities for philanthropic investment, but rarely are given enough in any one endowment for the purpose specified as that to which such endowment is to be applied. Their "general funds" are invariably depleted to bolster up the temporary or permanent needs of endowed departments, and the trustees are always embarrassed by deficiencies in the general account. Only those institutions which receive ample and regular income from the state for the regular and essential expenditures, and in which private munificence finds its field in adding the desirable but unessential, the comforts and the luxuries of higher intellectual life,

are certain of permanent and satisfactory success in their most vital work. The tendency toward a support of the universities, their foundation and adoption, by the State, as illustrated now so generally among the states west of the Hudson, is thus obviously to be regarded as one of the most encouraging and reassuring signs of the times. These states are carrying into effect the plan of education of the people for the work of the people which must constitute a main element in our future progress. They are also taking the course and adopting the plan which was sketched by the writer, years ago, in his plan for New Jersey.

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Cornell University is the State university of the "Empire State," yet nothing, practically, has yet been done by the State for its greatest institution of learning. All that has been done, thus far, has been accomplished through the energy, benevolence, and wisdom of private citizens. What may be accomplished in this manner is here an object-lesson to the world; but what may be accomplished when, at some future time, that State shall do its part in this the greatest work which falls to it to perform, can only be faintly imagined from what has already been accomplished without that aid and under a thousand disadvantages and difficulties that the State only can evade or remove, and under unimaginable obstructive conditions that the hearty and helpful assistance of the State in the past might have converted into enormously productive aids to advancement.

The magnitude of the work of technical education in the United States is greater than is usually supposed, notwithstanding the fact that it is so absolutely inadequate to the needs and opportunities of our country. The best authority of recent date, *Engineering News*, makes the total number of schools properly and regularly conferring degrees in engineering 94, while the number reported as conferring diplomas in science, among which are many doing some real professional work, outside the list of 94, is about 240. Of the larger list, 216 are found to have conferred 1,616 degrees in science and engineering in 1889, of which 993 were given by 75 colleges and professional schools recognized as entitled to rank with engineering schools of the professional type. The average number graduating from the engineering schools and colleges was 13.5, and from the other class 4.5, showing clearly the tendency of the professional and so called "practical" education to attract the American youth, and the inclination of the latter to desert the schools giving that purely gymnastic

education which was, until lately, the only recognized culture. It should, however, be remarked that the tendency to combine both lines of work by taking first the established academic courses, then entering the technical school, is beginning to become manifest and, at least in the writers's experience, with a somewhat rapid development and a most gratifying excellence of result.

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The accompanying table, gives the statistics of graduates in mechanical engineering in the United States for a period of a quarter of a century to date, beginning with the year 1868, when the Massachusetts Institute of Technology sent out its first class, the Sheffield Scientific School a single graduate, and the Troy Polytechnic a class, large for the time, of five members—seven young men that year entering their professional careers in this branch. In 1892 the total number is seen to be 445, and the number of colleges reported as graduating students in this course is over thirty, and their graduates in mechanical engineering averaging, for the last year reported 14, and ranging from 1 to 79 (Sibley College, Cornell University.) Eight colleges graduate twenty or more, each. The sub-division of electrical engineering has come in within the ten years just closing and has rapidly grown to include, in the larger schools, about one-half of all taking the mechanical engineering work. In schools as Sibley College, in which this branch is made a special feature, more than one-half of all students sometimes take it, either with a view of making it a specialty after graduation, or with the assumption that every mechanical engineer must, to-day, be somewhat familiar with the peculiar work of the electrician and of the electrical engineer. In other schools, as the Stevens Institute of Technology, in which no distinction is made, it is expected that all students will secure sufficient familiarity with this subject to prove themselves competent, later, to enter upon that line of special work.

A large part of this extraordinary growth of the electrical branch is a real and healthy extension of the list of specialized lines of engineering which is constantly growing longer as the work of the profession of engineering becomes more complex. No such extension in any branch of construction has been witnessed since the introduction of the modern steam-engine by Watt opened the whole world of contemporary manufacture to mechanical engineers. The introduction to-day, of this new auxiliary of steam and water power has given a very similar impetus to all lines of power and energy transmission, and the

NUMBER OF GRADUATES FROM COURSES OF MECHANICAL ENGINEERING.

School.	1868	1869	1870	1871	1872	1873	1874	1875	1876	1877	1878	1879	1880	1881	1882	1883	1884	1885	1886	1887	1888	1889	1890	1891	1892	School.
1. Rensselaer	5	5	8	4																						Rensselaer.
3. Yale	1			2	(4)	10	6	9	(9)	(7)	(7)	(7)	(9)	(9)	(9)	(9)	(12)	16	(20)	(18)	(21)	(20)	(29)	50	49	Yale.
6. Univ. of Michigan																1		1	1	6	7	6	7	7	9	Univ. of Michigan.
Totals, Group A	6	5	8	6	4	10	6	9	9	7	7	7	9	9	9	10	12	17	21	24	28	26	36	57	58	
9. Columbia																								5	6	Columbia.
11. Mass. Inst. Tech.	1	2	2	2	1	2	4	6	9	6	2	8		5	5	7	6	8	33	25	42	40	45	49	61	Mass. Inst. Tech.
12. Lehigh		1	2	1		2			3		5	2	2	1		7	4	4	6	12	14	12	9	13	19	Lehigh.
13. Univ. of Virginia																								1		Univ. Virginia.
Totals, Group B	1	3	4	3	1	4	4	6	12	6	7	10	2	6	5	14	10	12	39	37	56	52	54	68	86	
15. Tufts																			2	5	1	3	7	7	8	Tufts.
16. Univ. Georgia						1	2	1		1						1		1	1	1	1		1		1	Univ. of Georgia.
18. Washington U					1							2		2			1		1	2	4		2		4	Washington U.
20. Kans. Agr. C				(4)	(2)	(1)	(4)	(1)	(4)	(6)	(3)	(6)	(5)	(6)	(6)	(8)	(12)	(10)	(14)	(14)	(15)	(17)	(18)	(26)	(20)	Kansas Agr. C.
21. Worces. Poly. Inst.				6	4	10	9	11	4	11	9	12	11	12	17	14	14	17	18	17	21	23	18	20	22	Worces. Poly. Inst.
22. Ala. Poly. Inst																									2	Ala. Poly. Inst.
23. Me. Agr. Coll								3	5	4	1	4		3	5	1	1	4	3	4	6	2	15	6	8	Me. Agr. Coll.
24. Iowa Agr. Coll																								6	8	Iowa Agr. Coll.
Totals, Group C				10	7	12	15	16	13	22	13	24	16	23	28	24	28	32	39	43	48	45	61	65	73	
25. Univ. of Penn																								8	3	Univ. of Penn.
26. Stevens Inst. Tech						1	3	9	16	9	22	15	6	16	12	19	40	36	32	30	38	36	39	45	39	Stevens Inst. Tech.
27. Univ. of Wisconsin													1	1		3	5	5	4	4	5	4	3	7	8	Univ. of Wisconsin.
30. Cornell (Sibley Coll.)							3	3	4	2	5	5	5	5	6	7	10	7	10	19	24	33	60	52	79*	Cornell (Sibley Coll.).
32. Univ. of California										2	1	3		6	3		1			2	3	2	4	6	2	Univ. of California.
33. Univ. of Kansas																							3		1	Univ. of Kansas.
34. Univ. of Minnesota											1					1		1		1	2		3	3	6	Univ. of Minnesota.
35. Rutgers																								3	2	Rutgers.
38. Univ. of Illinois											4	1	2	1	5	1	1	5	5	5	2	3	11	7	4	Univ. of Illinois.
39. Univ. of Cincinnati																									(1)	Univ. of Cincinnati.
Totals, Group D						1	6	12	20	13	33	24	14	29	26	31	57	54	51	61	74	78	123	131	145	
41. Texas Agr. Coll																					5	3	3	6	7	Texas Agr. Coll.
42. Univ. of Nebraska																						1	1	2	2	Univ. of Nebraska.
44. W. Univ. of Pa																									2	W. Univ. of Pa.
45. Pa. State Coll																								6	5	Pa. State Coll.
46. Purdue																		2	5	1	5	6	4	8	17	Purdue.
47. Rose Poly. Institute																			15	8	10	4	10	14	23	Rose Poly. Institute.
50. Mich. Agr. Coll																					3	6	9	6	7	Mich. Agr. Coll.
51. Ga. Sch. of Tech																							2	8	20	Ga. Sch. of Tech.
Totals, Group E																		2	20	9	23	20	29	50	83	
Grand Totals	7	8	12	19	12	27	31	43	54	48	60	65	41	67	68	79	107	117	170	174	229	221	303	371	445	

* The reported number is less than the actual, which was 90 in 1892, and, including students taking second degrres, over 100 in 1893.

peculiar fascination of the subject as a branch of applied physical science has contributed to increase its attractions for ambitious and talented young engineers. The field will probably furnish place for a large body of these young men; but it is perhaps likely that the flood of applicants for opportunity to work in it will prove, presently, to be far in excess of the real demand, and frequent disappointment will check the singularly rapid growth of this division of the modern engineering school. The immense equipment required, also, and its commensurate cost of purchase and of maintenance and operation, tends to restrict the instruction given in this department to a few wealthy or large schools, and thus, in some degree, also, to put a brake upon this rapid acceleration. At the moment, however, there is no visible sign of a falling off of this growth or of the numbers finding employment in the work of transmission and application of electrical energy and of construction of the required "plants."

This development seems to have been peculiarly rapid and steady in the United States. Not only are there, apparently, no such schools of electrical engineering in the countries of Europe as in this country, but the number entering and graduating in such courses of professional study and training is nowhere else as large or as influential in determining the progress of the introduction of these recent improvements in power and light distribution. In this country, the student is taught in engineering schools the art of construction, as an engineer; in foreign schools, he is usually given admirable opportunities to acquire a good knowledge of the various branches of applied physics as involved in this branch of engineering, but is given little or no instruction in the essential, fundamental principles and practice of construction. He is made a physicist, not an engineer. This error is committed, in some instances, in this country, but only in colleges in which there are no facilities for engineering instruction, or where the work is attempted to be performed by men of science rather than by practitioners in this branch of engineering. The engineer who is a physicist succeeds; the physicist who is an electrician but not an engineer must inevitably and invariably fail in all engineering work—and the work of the designer, builder, and operator of any and every kind of electrical machinery is mainly that of the engineer.*

* It is as essential that the engineer familiar with this branch of construction should plan and direct the courses of instruction in electrical engineering as that the student should be instructed as an engineer. Our experience

The U. S. Department of Agriculture constitutes one of the several principal Government departments of which the heads are the members of the President's Cabinet. It was made a bureau originally (1862) under the Interior Department, and was erected into a department in 1889, with a Secretary of Agriculture at its head. It now includes fifteen sub-departments, and each is doing a large amount of valuable scientific work, and publishing results in its regularly issued bulletins for distribution to the agriculturists of the country.

Its work consists largely in the introduction of new varieties of domestic animals, new fruits, grains, vegetables, and in the distribution of seeds and other useful material to the farmers of the whole United States. It keeps watch of the sanitary condition of the country and of herds, provides for the reduction of epidemics and their prevention among domestic animals, prevents the adulteration of food products, and furnishes regular and frequent reports upon the condition of the growing crops. It coöperates with the agricultural colleges and experimental stations on the

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shows that it is a decided advantage that every subject taught in engineering schools should, as far as practicable, be taught by engineers or specialists practically familiar with engineering and its applications of their subjects. We even find great advantage in securing instruction in applied mechanics from members of the profession having a talent and special predilection for that subject. The absurdity of establishing engineering schools with non-professionals at their heads has slowly come to be recognized to be as great as that of the custom, formerly general, of putting a clergyman, as such, at the head of every college, and the folly of seeking to construct an engineering course to be taught by a non-professional is not less patent. It is probably this fact which accounts for the early and steady success of the Troy school, in which, from the first, the "director," the active, working head, has been at home in engineering practice. The organization of any professional school with any other than a professional expert at its head has come to be recognized as eminently absurd and dangerous. Eminent professionals at the head, and talented men practically experienced on the staff, are the primary elements of success in any engineering, as in any other professional, school, and a no less important element of success, perhaps, is also the placing of specialists in charge of special lines of engineering work. This is now always a feature distinguishing the larger and the better classes of technical school and college. A similar fundamental error is observable in the organization of many of the "Land Grant Colleges" established for the special purpose of promoting agriculture and the mechanic arts. The non-professional is placed where the professional should work. A baby should not only be "nursed by one who loves it," but by one who knows what it wants and how to supply it.

work of research, and, in general, promotes the interests of the agriculturists in all practicable ways.

The U. S. Department of Mechanic Arts does not exist, nor is there any special appropriation for this section of the work of the colleges founded for the benefit of "the industrial classes," either by the Federal Government or any State. The wonderful growth and flourishing condition of these colleges is due, wholly in many cases, greatly in all cases, to the sympathy and assistance given by private liberality. The bureaux of statistics of labor are the only governmental organizations doing anything specially to promote the interests of this section of those classes, and they can do but little more than aid the worker in finding the best market for his labor; they can do nothing to promote his education and to advance his experimental knowledge as do the "experimental stations" of the agriculturists. The establishment of a Department of Mechanics, similar to that now long organized for agriculture, was proposed twenty years ago by the late A. S. Cameron, of New York, but never obtained recognition, and nothing has been accomplished, even if anything has been attempted, since. The work which should be performed by such a department at Washington is done, so far as it is done at all, by the engineering schools and colleges, some of which have good departments of research and fine engineering laboratories. It would seem probable that, with the organization of such a department, under proper officers, the present neglect of the interests of these industrial classes might terminate and even our Patent Office be placed on a correct and equitable basis.

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THE CHARACTER AND MAGNITUDE OF THE OUTFIT required by the technical school of higher grade is seldom realized, even by the educator engaged in this department of education. Over $300,000 have been expended by Cornell University or given by its friends in the collection of its apparatus of instruction; and it is still reported to be desirable that it should be increased to meet the needs of the still growing student-body. It is of course, true that this equipment is useful in the university instruction of the students in the "general courses;" but the students in the engineering schools are those who mainly crowd the laboratories of pure, as well as of applied, science, and compel the collection of such immense aggregations of machinery and apparatus.

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THE MECHANICAL LABORATORY, the department of research of

the modern American engineering school, has come to be so important and essential a division of the most successful schools and colleges of engineering that an article should be specially devoted to this subject. Although not recent in origin or absolutely modern in form and purpose, it is only within a comparatively short time that it has taken its proper place in the organization of these schools and commenced that work which has come, to-day, to be recognized by engineers and educators alike to be the most fruitful of result, the most beneficial to the student, and the most productive of both knowledge and discipline of all the methods of instruction and of study and practice forming parts of the contemporary scheme of engineering professional instruction.

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The Sibley College Laboratory, at Cornell University, is the latest and perhaps most extensive of those now rapidly taking form in the United States, and especially in the Land Grant and State colleges. It was organized by the writer, in 1885, as a department of instruction, as well as of research, in that institution, and it has come to be already one of the largest and most productive of its various lines of work. It is supplied with a number of testing machines, ranging from 150, 100, 50, and 25 tons capacity down to the smaller torsion, transverse, and impact machines, with several experimental engines of from 150 or 200 down to 5 or 6 H. P., perhaps as many air and gas engines, and a number of oil-testing machines ; together with a sufficient number of steam-engine indicators, gauges and miscellaneous apparatus required to meet the needs of senior and junior classes numbering from 100 to 125 men. Many graduate students and some undergraduates take up work in research, and the laboratory is thus rendered doubly productive. Professors engaged in their own investigations find the aid of such students very advantageous in matters of detail, and they often produce original work of real value. Besides the experience and training of the laboratory, the student secures often a still larger training by taking part in work conducted elsewhere, as in the testing of engines by the commercial branch of the establishment, and the investigation of efficiencies of the heating "plant" or of the water supply and water-power machinery of the college. Such work as this, and especially such as is illustrated by the great investigations of Bauschinger and of Schroeter, of Wohler and Spangenberg, now universally familiar to the profession, is adding constantly and enormously to the store of facts and data upon which successful practice in construction depends.

These college laboratories now promise to supply such information more extensively and more systematically and with greater accuracy than can possibly any other means, with the possible exception of govermental laboratories like that at the Watertown Arsenal; which laboratories, however, rarely contain any large variety of apparatus or attempt more than a very limited range of work. In them the colleges find their most visibly fruitful work and the student his most productive line of study; while the profession and the world are, through them, securing larger and more useful contributions to the sum of human knowledge than perhaps in any other way or field of work.

THE EMERY TESTING MACHINE.*

The Emery Testing Machine, as made by William Sellers & Co., of Philadelphia, was represented at the Columbian Exposition by a machine of 200,000 pounds capacity, in operation in the Ordnance Section of the War Department Exhibit.

It is an hydraulic machine of the horizontal type, capable of taking in a tension specimen 5′ 5″ long and 2⅜″ diameter, or a compression specimen 7′ 8″ long.

By means of the hydraulic support and steel fulcrum plates invented by Mr. A. H. Emery, the machine is rendered sensitive to a pound, and retains its sensitiveness at all loads.

The hydraulic support consists of two flexible brass diaphragms forming the sides of a sealed chamber, and upon which the stress exerted upon the specimen is received. This chamber is filled with liquid, and connects by a copper tube of ⅛″ bore with a smaller diaphragm in the weighing case. On this smaller diaphragm rests a steel column which transmits the pressure, reduced in proportion to the area of the two supports, through a system of levers to the weighing beam. The fulcrums, by which the motion of these levers is conveyed from one to the other, consist of thin steel plates forced into the levers, so that the motion produces flexure of the steel plates, which, by their elasticity,

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*This machine, a picture of which forms the frontispiece of this number of the JOURNAL, was under the charge of Mr. Geo. B. Preston, in Chicago, this summer.

tend to return the levers to their first position, thus eliminating friction from the movement.

The method of weighing the load is also original with Mr. Emery. Three series of ten weights each are provided; the value of those of the first series being 100 pounds, the second series 1000 pounds, and the third 10,000 pounds; also one weight of 100,000 pounds.

By means of a hand lever projecting from the core, the weights of each series can be dropped one after the other upon rods hanging from the scale beam. Indexes operated by these handles show at any time the weight on the beam. Connected with the beam by steel tape is a slender pointer, the position of which shows whether or not the beam is balanced, and also indicates 10 pound increments of load up to 100 pounds. By means of a sliding poise upon the beam, loads can also be weighed by 1 pound increments up 100 pounds.

The hydraulic pressure for operating the straining piston is produced by a three throw plunger pump, with adjustable length of stroke for different speeds of testing.

The cylinder can be moved along the frame to suit different lengths of specimens, by nuts working upon the large screws which connect the cylinder with the housing of the hydraulic support. These nuts are driven by differential gearing, which insures that each side of the cylinder is moved at the same rate, thus preventing binding upon the ways.

Tension specimens are held in self centering conical wedges, which are made to grip the specimen or release it, by worm gearing actuated by a hand wheel.

The compression heads are provided with spherical seats, so that they can accomodate themselves to angularity of the faces of the compression specimens.

The machine is of wide adaptation, both as regards size of test pieces and speed of testing, is sensitive and accurate to the last degree, and will prove of great value to the engineering world, especially in work of investigation.

The electrical instrument known to the trade as the Ryan electrometer, originally designed by Professor Ryan, received an award for excellence at the Columbian Exposition. The instrument is manufactured by Queen & Co., and by them exhibited at the fair.

LOSSES IN TRANSMISSION OF HEAT.

BY PROF. R. C. CARPENTER.

The convenience of having all the boilers of a steam plant at one point has frequently led to the adoption of methods of conveying steam long distances, either for power or heating purposes. For such uses it becomes of much importance to determine the amount and character of the losses which occur, in order that the economy of the operation may be determined.

It is evident that, for heating plants, this method will usually come in competition with the ordinary methods, where heat is applied in each building, and it is desirable to know whether the inevitable losses which occur in the line conveying the heat do not overbalance the saving due to the greater economy which can always be secured by the large steam plant.

When power is needed in various places at some distance apart, several methods present themselves. (1) One large plant from which mechanical power is obtained, and transmitted by long lines of shafting, or ropes or belts. (2) One large power plant from which power is obtained, and transformed into electrical energy, in which condition it is transmitted to electric motors, which perform the work. (3) Separate and complete steam plants located where the work is to be done. (4) One large boiler plant with separate engines, steam being transmitted in pipe lines to the various engines, located where the power is needed.

While it is not in the province of this article to discuss the peculiar advantages and disadvantages of these various systems, each of which has its strong advocates, it may be mentioned that circumstances may act to make one or the other system the more economical under certain conditions. A few words regarding the different systems may be appropriate.

In the first system the losses are due principally to friction. This is usually nearly a constant loss, independent of the total power transmitted, and is frequently an excessive amount. In a recent test of a large cotton mill, made by the writer, the power absorbed by the friction of the main and countershaft was over 330 horse-power. The total power of the engine used to drive the mill was 1050 horse-power. In this case over 30 per cent. of the full power was lost in transmission, and it is not an unusual or extreme case of this character.

With electrical transmission there is first a loss in transforming mechanical into electrical energy, and second a loss in re-transforming electrical into mechanical energy. The electrical generator is seldom above 70 per cent. in efficiency, and the motor seldom above 80 per cent. but if we consider the generator efficiency as 80 per cent. and the motor efficiency as 90 per cent. we will have a total efficiency of 72 per cent. indicating a loss by this method of transmitting power, of at least 28 per cent. This we may reasonably suppose to be reduced by improved appliances and great care to 20 per cent., if not now, at least early in the future.

The use of separate and complete plants is the alternative for all these systems, and of course signifies the production of power, if we may use that expression, at the point where the work is to be done. It is open to the objections which attend the use of numerous boiler plants, and the want of economy characteristic of small plants. It means larger operating expenses and greater wastes, consequently this system of power distribution is not often employed unless the distances are very great.

The distribution of steam from a central boiler plant to separate engines, is often practiced; and the amount and character of the losses which occur will no doubt be of general interest. The discussion of such losses as occur in the transmission of steam, either for heating or power purposes, is the principal subject of this paper.

LOSS IN TRANSMISSION OF STEAM FOR HEATING.

Heat for the buildings of Cornell University is obtained from a boiler plant at Sibley College, on the north side of the Campus, and is transmitted by pipe lines laid underground to the various buildings constituting the University.

The pipe is laid in nearly a direct line to the various buildings, and is protected from heat losses by a wooden pipe; the pipe being made of a solid log, from which the central portion has been removed by a cylindrical saw. The bore of the wooden pipe is two inches greater than that of the iron pipe which is inclosed, and the thickness of the wood wall composing the pipe is four inches, thus making the outside diameter of the wood pipe nearly ten inches greater than that of the inclosed iron pipe. The outside of the wood pipe is turned, protected by a spiral winding of hoop iron, and coated on the outside with hot coal tar and saw dust. It is seen that it insures for the steam pipe an air space of

nearly one inch, and four inches in thickness of wood covering. (Fig. 1.)

The expansion of the line is provided for by variators made by the Holly Mfg. Co. of Lockport, N. Y., which are located 50 feet apart. The line consists of 150 feet of 10-inch steam pipes and 2,050 feet of 6-inch pipe, having a total heating surface of 5,605 square feet. The pipe line was laid in 1889, and a test was made by Mr. Churchill within a few months of its completion.

For ascertaining the heat losses, Mr. Churchill employed several methods. In one method sections of the line were taken, and calorimeter observations made on the steam as it entered and left the line. The result of this investigation indicated a loss of heat in a distance of 2,025 feet of nearly 10 per cent. of the heat transmitted. The other method of determining the loss was to ascertain the amount of heat required to keep the line heated to its working condition, this being done by closing off all the buildings, and making certain that there were no leaks existing in the line. The heat required was determined by a boiler test.

Mr. Churchill considered this the more satisfactory method, although the results did not differ essentially from those obtained by the first method. The trials were made, the results being as follows:

LOSS IN BRITISH THERMAL UNITS.

	Difference of Temperature.	Total per Hour.	Per deg. difference of Temp.	Per sq. ft. Surface.
1st Trial	241°	1,021,370	4,237	.755
2d "	235°	811,047	3.452	.614
3d "	236°	932,110	3,991	.712

The first trial was made when the ground was very wet, and some soil water reached the pipe. The third trial was made under unfavorable circumstances. For these reasons the second trial is considered as giving results which represent the pipe line under best conditions.

The loss per square foot for a naked pipe, under the same conditions would have been 570 B. T. U., which is equivalent to 2 B. T. U. for each degree difference of temperature. That is, the heat loss in the plant tested is 30.7 per cent. or that in a naked steam pipe.

LOSS IN TRANSMISSION OF HEAT FOR POWER.

The surplus coal of the Lehigh Valley system, destined for the New York market, is unloaded by the Dodge system of coal handling machinery, stored in enormous conical piles at South

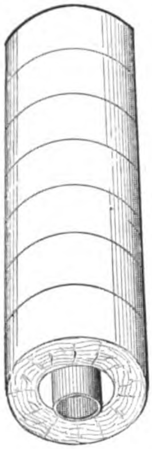


Fig. 1.

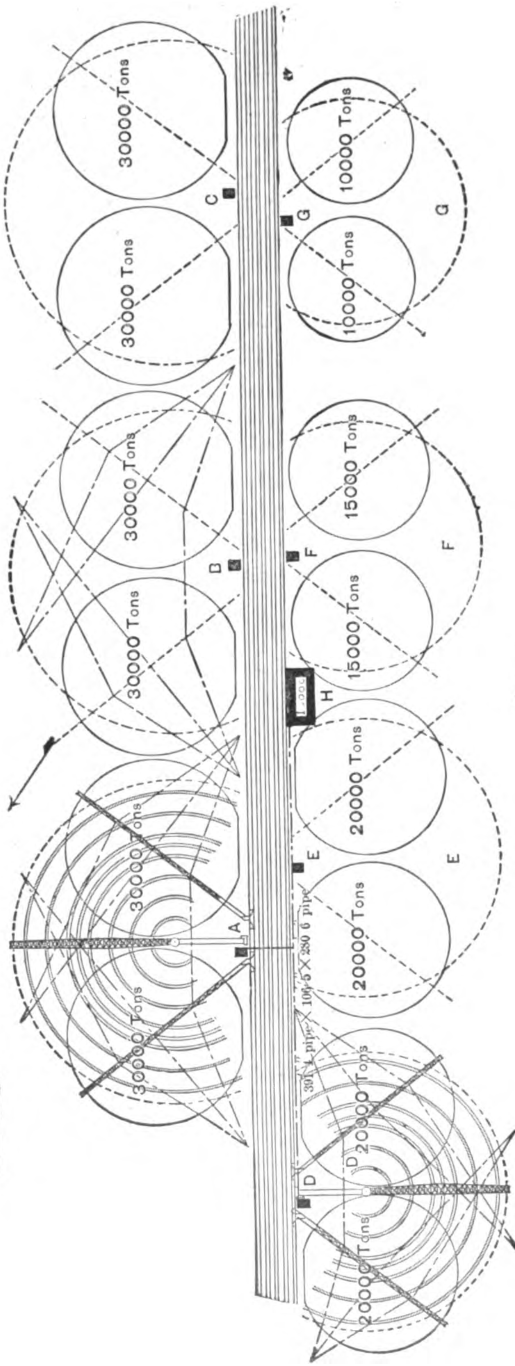


Fig. 2.

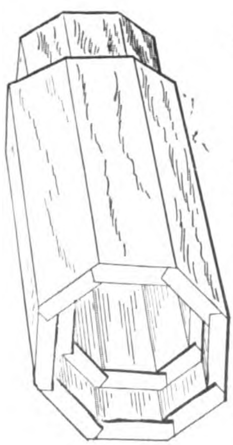


Fig. 3.

Plainfield, N. J., and then reloaded as the state of the market demands. The coal is distributed on either side of the track for a distance of 1,500 feet. The unloading and reloading machinery is heavy, and requires in each case enormous power which is only in occasional use, so that the problem in this case is, most efficient distribution of power to the various coal handling plants. The system adopted was that of independent engines, provided with steam from a central boiler plant.

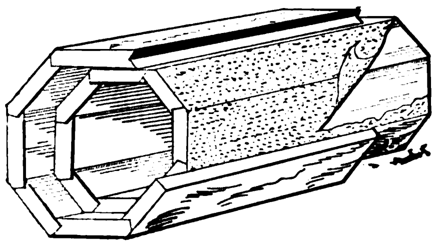


FIG. 4.

The general map of the plant, with principal dimensions, are shown in Fig. 2. The boiler plant is located at *H*, and steam is conveyed to the various engines designated by the letters *A*, *B*, *C*, *D*, *E*, *F*, and *G*. The engines are in each case simple automatic engines, made by the Buckeye Engine Co., and vary in capacity from 75 to 150 horse power. They are operated only when the machinery to which they are connected is required. At other times no steam is supplied to them.

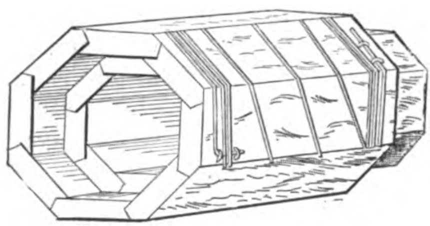


FIG. 5.

The steam is conveyed to the engines in piping which is protected from heat radiation by the Wyckoff covering as now manufactured at Elmira, N. Y., by A. Wyckoff & Son. It consists of two concentric octagonal pipes, each built of one inch plank and separated from each other by a very thick layer of water proof paper. The form of this covering is shown in Figs. 3 to 6. Fig. 3 represents a section of the casing complete. Fig. 4 shows pipe with a portion of the outer covering removed showing paper. Fig. 5 shows coating removed from two staves showing galvanized wire with which casing is wound. Fig. 6 shows the manner

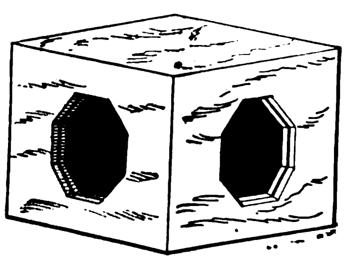


FIG. 6.

of casing tees and elbows. The top is put on with screws, and can be easily and quickly removed when necessary. The steam pipe is laid in the center of the wooden pipe, and is surrounded by an air space about half an inch across.

At South Plainfield this pipe was not buried in the ground, because of the wet character of the soil and the difficulty of securing proper drainage, but was left on top of the ground, and protected by a rough wooden box constructed of two inch plank. The outer box is far from tight, and air enters freely at numerous cracks and holes, so that, except as a mechanical protection for the inner wood covering, it cannot be considered of great value, and is certainly inferior in non-conducting properties to a covering of earth.

The boilers for the plant are six in number and are a vertical type of plain tubular boiler, built by the Stearns Mfg. Co., Erie, Pa. They are 6 feet in diameter, 18 feet high, and contain 316 flues, each 3 inches in diameter. Four of the boilers are sufficient to operate the plant at its usual capacity.

The expansion of the line is poorly provided for, there being one plain expansion joint and two offsets. The expansion joint is badly out of line, is located near the boiler house, and is practically inoperative. The result is, that when a given line is heated up, a great increase of length occurs, which is permitted by the branches leading to the various engines, but which, nevertheless induces severe strains both in the pipe itself and in the outer wood covering.

The test of heat losses was made by myself, assisted by Messrs. Dunn and Mack, of the class of 1893, in Sibley College, Cornell University. The test was made only of the west line, and was confined to measurements of the loss of heat between the boiler house and D engine. The test was made Feb. 17, 1893, and was of eight hours duration.

Total length from boiler house to D engine, 747 feet, consisting of 250 feet of 6-inch, 106 feet of 5-inch, and 391 feet of 4-inch pipe, having a total radiating surface of 1,057.5 square feet. The line leading from the boilers is of 6-inch pipe to E engine house, then 5-inch pipe to the branch leading to A engine house, and the remainder of the distance is 4-inch pipe.

The engine was a 12 by 16, running with a piston speed of about 600 feet a minute, thus requiring, when cutting off at one-third stroke, a velocity of the steam of about 60 feet per second in the 4-inch supply pipe. As this pipe was 391 feet long, more

reduction in pressure was anticipated than was actually found. As shown by the summary which follows, the actual reduction varied from 5 to 7 pounds, averaging 6 pounds.

The general method of testing adopted was such as to give information, first, as to the amount of water in the steam as it entered the steam pipe; second, the amount of water in the steam as it reached the engine; third, the amount of water collected at intervening drips; fourth, the total amount of steam used; fifth, the fall in pressure between the boilers and engine. These determinations were made as follows: The amount of water in the steam was determined by a throttling calorimeter, the sample of steam being drawn, in each case from a vertical pipe located close to a bend from a horizontal, and collected by a half-inch nipple extending past the center of the vertical pipe. The drip was caught at places which had been provided in the pipe, and was weighed from time to time.

The boiler gauge was removed from boiler No. 1, and a test gauge, which had been compared with the standard mercury column at Sibley College and found to have an error of two pounds, was put in its place. Boilers No. 1 and No. 2 are connected by a large steam drum, and subjected to the same pressure. It was found by this comparison that the test gauge read the same as the guage on boiler No. 2, and that it read two pounds higher than the gauge on boiler No. 1. This would indicate that boiler gauge No. 1 was correct, and No. 2 and the test gauge two pounds high.

The barometer readings were taken with an aneriod which had been compared with a mercurial barometer. The corrected readings are given in the summary as well as in the diagram. Simultaneous observations of the quantities given in the summary were taken every ten minutes. A study of the summary shows that the loss was sensibly constant during the run. This is clearly shown by noting the fact that any increase in the amount of steam flowing through the line had the effect of decreasing the percentage of moisture at the engine.

The total loss per hour was equivalent to that required to evaporate $(36 + 45.1) = 81.1$ pounds of water from a temperature of 212° F., to a pressure of 70.1 pounds by gauge. This is equal to $(81.1 \times 993 =)$ 80,432 B. T. U. The average steam pressure was 70.1 pounds by gauge, its temperature 313.6° F., the average outside temperature 16.6° F., hence the difference of temperature was 297°. The loss for each degree difference of temperature be-

comes (80,432 ÷ 397 =) 269 B. T. U. per hour. The total radiation surface was 1057.5 square feet, hence the loss in B. T. U. per square foot per hour was 0.259 per degree difference of temperature.

The loss for a naked steam pipe under the same conditions would have been 2.93 B. T. U. per square foot of surface per hour, or the loss of the covered pipe is reduced to 7.87 per cent. of the bare steam pipe. The entire loss for the transmission is equal to the coal needed each hour to evaporate 81 pounds of water, which can be approximately stated as 10 pounds, since the evaporation of 8 pounds of water by 1 pound of coal is not an unreasonable assumption. Expressed as a percentage of maximum capacity of the line, this loss will not exceed one per cent., although it reached 2.3 per cent. of the maximum heat transmitted during the test.

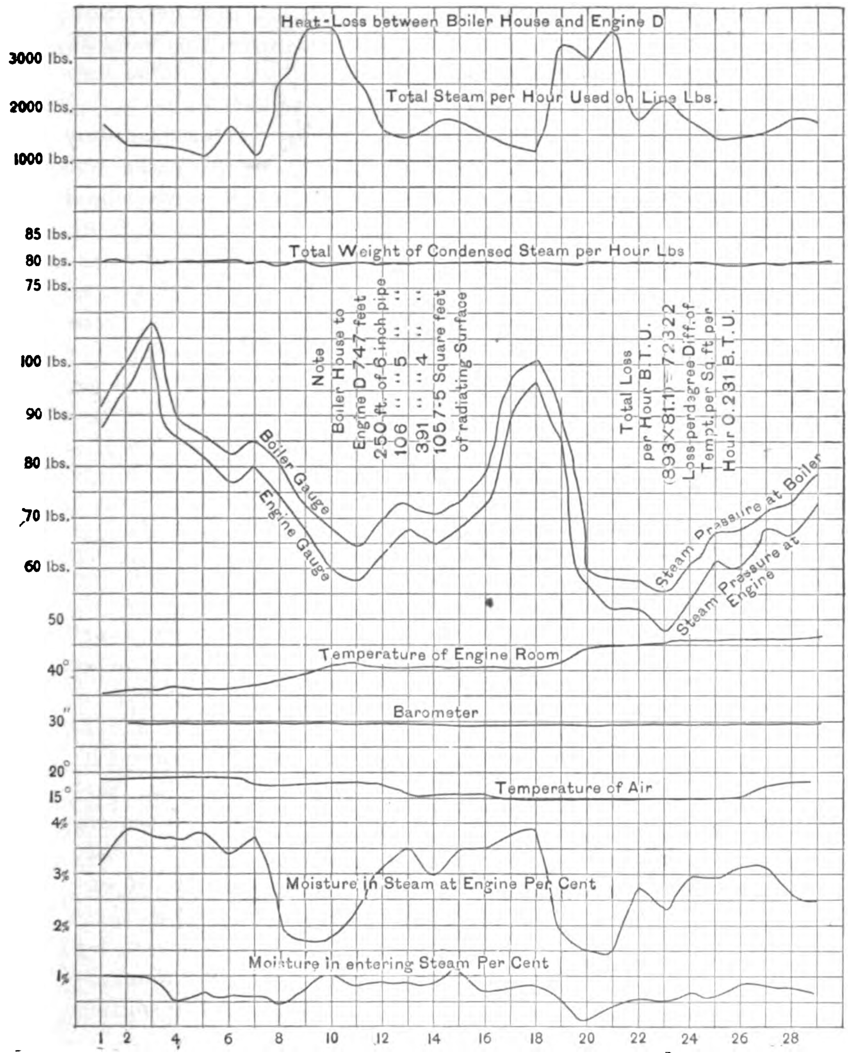
SUMMARY OF TESTS OF LOSS OF HEAT, LEHIGH COAL STORAGE PLANT, SOUTH PLAINFIELD, N. J.

	Gauge Pressure.		Temperature. (a) (b)					Moisture in Steam.				
No.	Boiler.	Engine D.	Boiler house.	Engine house.	Outside air.	Calorimeter entering steam.	Calorimeter steam at engine.	Entering steam.	At engine.	Increase.	Total weight of steam in line.	Remarks.
	lbs.	lbs.	F°	F°	F°	F°	F°	Per ct.	Per ct.	Per ct.	p h. lbs.	
1	92	87	38	36	19	275	228	1.0	3.2	2.2	1700	*E* Engine only running light.
2	101	96	...	37	19	....	213	1.0	3.9	2.9	1300	
3	108	105	...	39	19	....	213	1.0	3.8	2.8	1305	
4	89	86	38	38	19	284	217	0.5	3.7	3.2	1190	
5	86	82	38	38	19	280	214	0.65	3.8	3.15	1080	
6	83	77	38	38	19	280	220	0.6	3.4	2.8	1700	*E* Eng started loading cars. *D* light.
7	85	80	38	38	18	283	214	0.49	3.75	3.26	1100	
8	80	74	38	38	18	281	247	0.45	1.9	1.45	2500	
9	73	67	44	40	18	272	243	0.75	1.7	0.95	3600	
10	68	59	42	40	18	264	239	1.03	1.75	0.72	3600	
11	64	58	46	41	18	266	229	0.75	2.25	1.50	2510	
12	70	63	38	41	18	267	216	0.9	3.2	2.03	1600	*E* Engine running light. *D* Eng. also light.
13	73	68	38	41	16	270	213	0.85	3.5	2.15	1500	
14	71	65	38	41	16	268	225	0.85	3.0	2.15	1800	
15	73	68	38	41	16	264	213	1.2	3.5	2.3	1800	
16	78	73	38	42	16	275	214	0.7	3.5	2.8	1500	
17	98	91	38	42	15.5	282	212	0.75	3.8	3.05	1300	
18	101	97	38	46	15	284	220	0.8	3.9	3.01	1200	
19	88	86	38	47	15	282	251	0.6	1.95	1.35	3300	Engine *D* loaded, *E* run light.
20	59	58	42	47	15	282	250	0.0	1.5	1.5	3000	
21	58	52	42	47	15	282	239	0.45	1.5	1.5	3650	
22	58	52	48	47	15	267	214	0.55	2.8	2.25	1800	
23	56	48	50	48	15	267	222	0.5	2.3	1.8	3200	
24	61	55	50	48	15	267	212	0.75	3.0	2.25	1800	Engines *D*, *E* and *A* run light.
25	68	62	50	48	15	266	212	0.6	3.0	2.4	1500	
26	68	60	50	48	15	266	214	0.9	3.2	2.3	1500	
27	72	68	50	48	15	270	213	0.8	3.2	2.4	1600	
28	73	67	50	48	18	270	228	0.8	2.6	1.8	1800	
29	79	73	50	48	18	276	228	0.65	2.5	1.85	1800	

Average amount of water caught in drips, 45.1 pounds per hour.

Average amount of water indicated by calorimeter, 36 pounds per hour.

The diagram shows the variation in the various quantities which occur at each observation during the test. It will be noted that the total loss expressed in pounds of steam condensed remained practically constant. This has the effect of decreasing the percentage of moisture present in the steam when the total amount of steam passing through the line increased. It is also



of interest to note the parallelism of the two lines which represent respectively the pressure at the boiler and at the engine, nearly 750 feet distant.

These figures compare favorably with any other method of power transmission, even when the fact is considered that the line during the winter months is kept hot night and day, while the power is actually used only during the day. This would not at

the most more than double the latter number, and even if considered would not make the loss of power transmission exceed five per cent. of that required to do the work.

A comparison of the two methods of protecting steam pipe shows the following. Column A is for pipe under ground and protected by solid wood piping with shell four inches thick. Column B is for pipe in square wooden box and protected by the Wyckoff covering 2 inches thick.

	A.	B.
Loss in B. T. U. per sq. ft. of surface, and per degree difference of temperature	0.614	0.259
Per cent. that loss bears to that of a naked steam pipe under the same conditions	30.7	7.9
Relative value of covering	1	2.37

It is not the object of this paper to make any comparisons between different systems of transmitting power, or of heating buildings, and with a single remark the conclusions will be drawn.

SUMMARY AND CONCLUSIONS.

At Cornell University the various buildings had been heated by separate plants before the introduction of the system described. After the introduction of the new system, it was found that, despite its large wastes, the buildings were heated better and more economically than before; chiefly due to the fact that the new boiler plant was made more efficient, and was arranged so that a cheap grade of coal could be successfully burned, yet as shown by the forgoing tests the heat losses might have been reduced by a better covering to less than 40 per cent. of those actually found.

It is easily possible to calculate the surface required to condense one pound of steam from the data given in the tests. Thus, to change one pound of steam at atmospheric pressure into water at a temperature of 212°, 967 B. T. U. must be absorbed.

The loss in transmitting power by any system is largely constant, and hence when the power is greatly increased the percentage is correspondingly reduced. The following estimate is based on the transmission of 100 horse-power 1,000 feet.

METHOD OF TRANSMISSION.

	Per ct. of loss.
Line Shafting:	
Loss by friction . . . (average 25)	15 to 40
Electricity:	
Loss in transforming from mechanical to electrical and *vice versa*	20 to 30
Line loss	2 to 5
Total loss	22 to 35
Conveying steam:	
Naked steam pipe (still air)	37.6
Pipe covered with solid wood and earth	11.2
" " " " " Wyckoff's covering	4 8

In making the test, we were placed under many obligations to Mr. J. I. Kinsey, master mechanic of the Lehigh Valley R. R., and to Mr. L. E. Molineaux, the superintendent of the coal storage plant, for assistance in preparing for and conducting the test.

Since the table gives the loss caused by each square foot of surface for a difference in temperature of one degree between the steam in the pipe and the medium outside, we have only to divide 967 by the product of the number representing the difference of temperature and that showing the loss. Calculation made in this manner gives the following values for the amount of surface expressed in square feet required to condense one pound of steam.

SURFACE REQUIRED TO CONDENSE ONE POUND OF STEAM.

Condition of Pipe.	Difference of Temperature between Steam and Air.		
	1°	180°	200°
	Sq. Feet.	Sq. Feet.	
Naked Pipe.	483	2.7	2.4
Pipe, protected solid pipe (case A)	1570	8.7	7.8
Pipe protected, Wyckoff covering (case B)	3704	19.6	18.8

A PURELY GEOMETRICAL TREATMENT OF THE PLANIMETER.

BY C. H. BIERBAUM, M.E.

The following demonstration of the theory and proof of the Planimeter may appeal to some more than the usual calculus method. Only two preliminary propositions need be considered.

The area swept over by a line moving in a plane is equal to the length of the line into the perpendicular component of the distance moved by the mid-point of that line.

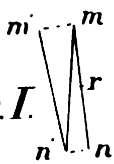


Fig. I.

Let $m\ n$ (*Fig. I*) be such a line, and r the mid-point of $m\ n$. If m rotate about n to m', then will the area of $m\ n\ m'$ be equal to $m\ n$ into the distance traveled by r. If m move to m', and n to n', then will the area swept over $m\ n\ n'\ m'$ be equal to $m\ n$ into the perpendicular component of the distance traveled by this point r. This demonstration is general for any motion of $m\ n$.

The area swept over by a line, whose extremities describe complete areas in the same plane, is equal to the difference of the areas described by the extremities of that line.

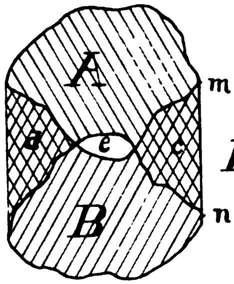


Fig. II.

Let $m\ n$ (*Fig. II*) be such a line, and let A and B be the areas described by m and n respectively. Taking the areas swept over from right to left as negative and from left to right as positive; then will the small areas c and d be both positive and negative, and e common to both A and B; therefore, the area swept over is equal to the difference between A and B.

COROLLARY.—*The difference of areas described by the extremities of a line moving in a plane is equal to the length of the line into the algebraic sum of the perpendicular components of the distances traveled by the mid-point of the line.*

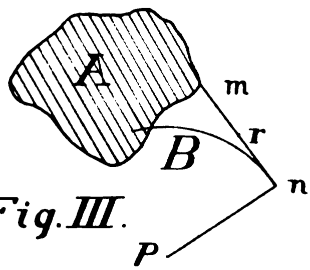


Fig. III.

Let $m\ n$ (*Fig. III*), represent one arm of an Amsler planimeter, m the tracing point and n the pivoting point, also let $n\ p$ represent the other arm with p the pole. Take r the position of the record wheel, equidistant from m and n. By the conditions of the construction of the instrument, if the tracing point m describe the figure A the point n follows an arc of a circle with the center p, and the difference of the areas described by the extremities m and n is equal to the area A, since $B = 0$. If l represent the length of the arm $m\ n$ and r the resulting record of the record wheel, the general formula for the Planimeter is thus established, $A = lr$.

The motion of the arm *m n* is one of two, or more often the combination of the two following motions: first, *m* swinging around *n* as a centre, or a rotary motion; second, a lateral or translatory motion. An area having been described and the tracing point *m* again brought to its starting position, the angle of rotation will then have been equally positive and negative, and thus the rotating motion has no resulting effect on the record of the record wheel; the motion of translation only is recorded. The proof is, therefore, general; and the record wheel may be conveniently located not necessarily equi-distant to *m* and *n*.

STEAM ENGINE DESIGN.

BY JOHN H. BARR.

It may be safely asserted that no branch of designing involves a more complex system of considerations, requiring more pains-taking study of both broad principles and of details, than steam engine design of the present day.

Numerous types, each having characteristic advantages, have been perfected to such a degree that they compete on very nearly equal terms, in many varieties of work. In electric railway and lighting plants we see the slow speed Corliss engines, the high speed Westinghouse, and every intermediate type of the better grade of engines. The somewhat higher economy of steam in the long stroke, slow speed, four valve engines is partially, or wholly compensated by the lower first cost, economy of space, and other commercial advantages of the smaller, high speed engines. The economy (within the engine itself) of a single engine of large capacity, is offset by the advantages of subdivided power, and saving in intermediate machinery of transmission, incident to a larger number of smaller engine units. The problem, embracing as it does, many conflicting engineering and commercial elements, is exceedingly intricate, and there is anything but unanimity, among unprejudiced authorities, as to the best type.

The type having been determined, after carefully weighing the relative advantages of all the better forms, success or failure depends upon the attention given to details.

Many important portions of the theory of the actual engine have yet to be developed; notably those pertaining to the phe-

nomena of cylinder condensation and re-evaporation, among the thermal considerations ; and the proportioning of many of the parts, among the purely mechanical considerations. The science of thermo-dynamics is highly developed, and has clearly defined certain limitations ; but it throws little light upon the all important heat transfers within the cylinder of the real engine. The mathematical theory of the strength of materials, make possible the accurate computation of stresses due to simple loadings ; but the complicated straining actions brought to bear on the members of a steam engine, due to pressure of steam, inertia of parts having motions variable in both direction and velocity, to centrifugal action, temperature effects in operation, initial stresses due to casting and to other methods of manufacture and manipulation, and various other elements, accidental, unforeseen or not calculable, render computations based upon mathematical deductions very unreliable, unless tempered with a large and variable amount of good judgment.

Rational reasoning and computations are desirable as checks upon the designer's judgment, and as valuable suggestions ; but in few of the problems which he is called upon to solve, are they, alone, to be implicitly relied upon. In many minor matters of detail, only less important than the principal considerations, precedent and experience furnish the only guides.

The process of designing a steam engine is then more of an art than a science. While many of the exact laws of the science have not been formulated ; the limitations of the art are well understood in a general way, at least by all intelligent designers. Starting, thus, on comparatively even terms, the winners in the severe competition of to-day are those who exercise the keenest insight, soundest judgment, and most untiring energy, in attention to the small things that make up the whole.

Of course there are instances in which poorly designed and constructed engines have met with large sales ; often, even, when well known principles have been sadly neglected. In some cases for instance, economy of fuel is not even of secondary importance, as in saw mill practice in certain sections of the country, where the refuse of the mill can not be disposed of by the most wasteful steam plant. In fact, the demand for the engine that will require the most steam, and the boiler that will furnish the least for a given consumption of fuel, are real wants in some such cases. Here the penalty for the violation of the laws of good practice is not enforced ; and paradoxical as it may seem, the best engineer-

ing possible is about the worst engineering conceivable. Ability to withstand rough usage, and low first cost, with sufficient power, and reasonable immunity from accident, are the primary considerations in such practice. In the higher grade engines, the conditions are more rigorous, and not only in fundamental principals but in the smallest items in any way affecting the operation, must the best practice of competitors be equalled or excelled.

In the design of nearly all important machines—and the steam engine is no exception,—adaptability, strength and stiffness, economy in cost of construction and operation, and appearance, are leading considerations.

The first requirement of a steam engine is that it shall utilize the energy derived from the fuel, and stored in the steam, in overcoming resistance. This usually implies the turning of a shaft which delivers the energy in a form available for useful work. There are numerous exceptions to this, however, notably in many pumping engines.

It sometimes happens that little more is required of the engine than that it shall turn the shaft against the resistance ; in other cases, preëminently in electric lighting, the shaft must turn with the greatest possible regularity under all changes of load and steam pressure.

Breakages and injuries to members of the engine which necessitate shuting down are always annoying ; usually expensive (directly and indirectly) ; and often, if frequent, they seriously affect the commercial success of the enterprise depending upon the engine. Especially is this the case in public service such as water works, lighting and railway systems.

Some appreciation of the responsibility of the designer may be realized ; when one considers how very exacting many of these duties are,—perhaps demanding the continuous running of the plant for nearly or quite twenty-four hours per day, and seven days in the week,—and that a slight derangement of a minor part may compel suspension of operation. This responsibility does not end in simply securing sufficient strength to resist any ordinary, or even probable, stress that may occur ; but it requires the utmost precaution in providing for every contingency that can be reasonably conceived to be among the possibilities. Lubrication must be sufficient and reliable, both as a measure of safety and economy. In the absence of good construction and constant lubrication, there is serious danger of delays and of injury to the

engine ; and furthermore, all unnecessary frictional work represents an equal reduction in the energy available for useful purposes, or a corresponding waste of steam and fuel.

It is especially important to attend to this matter carefully in the case of a high speed engine with long continuous runs. This has led to the design of such engines as the Westinghouse and "Ideal," in which the moving parts run in an oil bath. An Ideal engine, now at the Columbian Exposition, is said to have run 740 hours (nearly 31 days), with one oiling, and without a single stop.

After the various requirements of the service as to capacity, speed, regulation, reliability, strength, stiffness, steadiness and smoothness of running, etc., have been carefully provided for, the question of economy must be considered. This involves first cost, and the cost of operation and maintenance. The relative importance of these two items is seldom the same in any two isolated cases. First cost is always an item of importance to purchasers ; economy of fuel becomes more important, relatively, as its cost becomes greater ; oil is by no means a small item in the expense account of large plants ; cost of labor, taxes, insurance, etc., all affect the problem. Complications and refinements may be desirable means of reducing the fuel bill, but they involve greater first cost ; more and better attendance, or in lieu of the latter, greater liability to accident. In fact, without superior skill in the manipulation, care, and adjustments, the primary object of refined construction may be defeated.

Simplicity is a great virtue in a machine, and unusual complication should only be introduced when it appears reasonably certain, after carefully weighing the evidence in the case, that the gain will be equivalent to a liberal return on the investment.

Under conditions which vary but slightly, or for very limited periods during the operation, high economy at the normal loading is most important, as in marine engines. In other cases, as electric railway service, the engine may seldom run for any considerable length of time at its rated capacity, and high average economy through a wide range of load is more important than maximum economy at one particular load.

Last, and perhaps least, but by no means unworthy of attention on the part of the designer, is the consideration of *appearance*. Symmetry, good lines and proportions, smooth castings, good finish of parts that are finished, and general neat and workmanlike appearance are not only pleasing to the eye, but they have a

decided commercial value. Good appearance does not imply elaborate ornamentation and excess of bright work, much less the employment of high colors. It does demand that the metal be so placed that it will most advantageously meet the actions to which it is to be subjected. This usually calls for simplicity in form and directness in disposition of material; straightforwardness is as admirable in machinery as it is in men, but neither is the worse for having the corners gently rounded.

The points mentioned above, are but a very few of the very many requiring the attention of the conscientious designer. Anything approaching a complete treatment of the subject would fill, many times, the space available for the present article; and no more has been aimed at in this sketch, than to suggest some of the elements involved in steam engine design.

JOHN STEPHENSON.

"Honest John Stephenson" died in New York on the 4th of July, last, at the advanced age of 84. He was Irish by birth and descent, a consciencious, industrious, and capable workman, and became successful after taking up the construction of street-cars at the beginning of the period which has seen them made such a wonderful auxiliary in the transportation of passengers in our cities and towns. He started in business for himself in 1831 and speedily won a reputation for integrity, skill, reliability, and good work. He once failed in business, through no fault of his own, in a time of great general depression; but, on recovery of his business and with returning prosperity, he sought out his old creditors, one by one, and paid off every dollar of debts, in many cases long outlawed. It was this act which gave him his honorable appellation. A customer who ordered a carriage from him received a receipted bill representing the amount of an early, unpaid debt from Stephenson, and the latter declining to accept payment of the carriage in cash, the would-be purchaser draped it with colors and adorned it with a sign reading, "This is the way in which Honest John Stephenson pays his debts," and, thus decorated, sent it all about the streets of the great city, the noblest advertisement that ever a man had.

John Stephenson's business motto was "Never turn out a bad piece of work."

AN ELECTRIC RAILWAY ON THE CAMPUS.

BY HARRIS J. RYAN.

The proposition of the Ithaca Electric Co., to extend its railway line across the campus has recently created considerable discussion among our University people. The advisability of granting privileges of this nature to an independent corporation for doing business on the grounds and property of the University is a matter that our trustees have studied carefully, and one may rest assured that such privileges will justly be witheld so long as there is a shadow of doubt as to the good that is to result. The arguments in favor of the establishment of an electric railway over the University grounds have been mainly to the effect that the convenience and comfort of the present rapid transit service as it is, would be greatly increased for those who live on the campus or who are in attendance on duties there. The route generally proposed for such a line has been from South Avenue, where the present road ends, North between Sage College and Barnes Hall, just passing Boardman Hall on the East, and ending at President's Avenue. Such a route would be convenient if it were to extend entirely across the campus, and at the same time very objectionable because the trolley line would undoubtedly spoil the appearance of our beautiful lawns.

For a route that would be convenient and unobjectionable on the score of unsightliness we suggest that the road be extended from its present terminus along the north side of South Avenue to the west side of East Avenue, and then along East Avenue to Reservoir Avenue, and from there by an easy grade contour along the incline back of Lincoln Hall to the east side of the Sibley College buildings. The road by this route would not be unsightly. The poles supporting the trolley lines would be practically in line with the trees, the road-bed would remain part of the lawn, and the stranger on the Campus would be apprized of the presence of the road only by the passing of a car. This road could be constructed and operated with a facility and readiness that is not to be excelled by any other route, while nothing would be omitted from the convenience that such a road could provide.

By extending the road to Sibley College the value of the equipment of the school of Electrical Engineering for professional training and instruction would be greatly increased. Sibley Col-

lege would then be able to operate for student instruction, in the work of experimental engineering, its own car equipments under the conditions of actual practice. The prospect of the establishment of facilities for instruction of this nature was laid before the General Electric Co. last Spring, and a representative was sent here to look into the matter further. He made a very favorable report to the company, whose officers for a number of years have contributed generously to our equipment. Sibley College, owing to the generosity of the General Electric Co., is now in possession of three complete electric car equipments which will be installed in due season in such a manner as to bring before students the engineering principles and quantities involved in their commercial operation. This, however, can only be done with the best results when operating under the actual conditions of practice as suggested above.

COLONEL RICHARD T. AUCHMUTY.

Colonel Richard T. Auchmuty died July 18th, at the age of sixty-two. Colonel Auchmuty was of Scotch descent and had all the best characteristics of his race, both of personal character and disposition and in professional work. He was an Assistant Adjutant General of Volunteers in the United States Army, during the war, saw considerable service, and distinguished himself in many actions. He was badly wounded, and was retired in 1864. Colonel Auchmuty had some property and gave up the practice of his profession as an architect to engage in the philanthropic work of founding what are now famous trade schools in New York City. He had long been impressed with the serious aspect of the outlook for the young men of the country desiring to acquire trades, and to earn for themselves a respectable livelihood by the work of their hands. The trades-unions had succeeded in throwing the control of the whole labor-market, in the trades, into the hands of foreign workmen, and had almost completely excluded American boys, wishing to learn trades, from apprenticeships. The result was obviously to also destroy all prospect of securing good workmen for the coming generation, and to make it certain that the country must submit to having its work done partly by the immigrant workmen well-trained abroad, in small proportion, but mainly by inefficient and half-trained men picking up the trades

as best they could in this country. Systematic promotion of good workmanship, pride in the craft, and progress in every line, were at an end. He conceived the idea of founding trade-schools in New York City, in which young men of talent and ambition as mechanics could be given a systematic instruction and training which should, so far as it could be carried out, prove a substitute for the extinguished apprenticeship system of the earlier generation. With the coöperation of Mrs. A. Schemerhorn, he built such schools in the year 1881, and organized classes which were successfully carried on from that time to the present, with the result of doing more for the promotion of the great work which he desired to see inaugurated than even he had thought possible. Ambitious, capable, and skillful workmen were thus trained and sent out into the great cities of the country in considerable numbers, and with great advantage to themselves and to the nation. He expended about $50,000 in the erection of his first buildings, and the scheme was a success from the start. Another sum, $160,000, was then expended in extensions, and the schools have become, it is thought and hoped, a permanent institution. Prominent citizens of New York have interested themselves in the work, and the founding of trade schools, the most serious need of the country, seems likely to continue, following this excellent example, in continually increasing numbers. This, the great purpose of Ezra Cornell, in founding Cornell University, is one of the most promising directions of development of modern technical education, and Colonel Auchmuty will be forever remembered as a pioneer, and one of the greatest of the promotors of this essential part of the contemporary method of education of the "Industrial Classes." His memory will be always cherished by every patriotic citizen.

—"All things come to those who hustle while they wait" is the sensible and accurate motto which Mr. H. Walter Webb submits to the boy-readers of the *Chicago Interocean*, in an article on "Railroad Engineers," telling "how boys become masters of locomotives." It is a very apt variation of the old saying, and better fitted to the facts, especially as they develope in this country of ambition, push, and hard work.

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A copy of the first issue of the Sibley Journal of Engineering is sent to every student and alumnus of Sibley College, whose address is known. Those who do not intend to subscribe will please mark this copy "Refused" and return it to Andrus & Church or to the Postoffice; otherwise the receiver's name will be placed on the subscription list.

THERE is a vacancy on the Sibley Journal board, which is to be filled from the class of '95, by competition. Matter will be received until Nov. 10.

ANY subscriber to Vol. VII, who has not yet received his June number, may obtain the same, by notifying the Business Manager.

EDITORIALS.

WITH this number, the SIBLEY JOURNAL OF ENGINEERING begins its eighth volume. Early in the history of the University the technical students felt the need of a college paper devoted exclusively to their interests, for the printing of matter of a technical nature in the other college journals was looked upon in the light of an intrusion, or an imposition upon their readers; and justly so, if carried to any great extent. Consequently, in 1887, a board was organized, which, in March of that year, published the first number of what was then known as the CRANK. From the very first the new publication was a success and took a high position among papers of a similar character. Each succeeding year has seen changes for the better, but in 1891 a decided improvement was inaugurated. In that year the make up of the journal was altered by changing the paper on which it was printed, and cutting down the size of the page to what it now is. In 1892, a new cover was designed and the name changed to the SIBLEY JOURNAL OF ENGINEERING. The board was increased by the addition of associate editors in 1890, when Professors A. W. Smith, R. C. Carpenter, and H. J. Ryan were elected. In 1891, Professor J. H. Barr, took Professor Smith's place. The present board, at its first meeting, elected as an associate editor, Professor William F. Durand, Ph. D., Associate Professor of Marine Engineering and Principal of the Graduate School of Marine Engineering and Naval Architecture.

It has been the aim of the present board to publish a journal which shall fully maintain the high standard reached by preceding boards. Its intention is to publish matter which will be of a scientific and instructive nature, of interest to every one connected with the engineering profession. The editors will be glad to receive, at any time, the results of experimental or theoretical researches, that embrace ideas, of value, as bearing on the advancement of knowledge on scientific subjects.

ALTHOUGH no exhibit was made by Sibley College at the World's Columbian Exposition, yet both faculty and students were well represented. Dr. Thurston, Professor Carpenter, and Professor Ryan were members of the jury of awards, and devoted nearly all the vacation time to this work.

Dr. Thurston, although a member of the Board of Judges on Machinery, devoted most of his time to special work of a general and administrative nature. At the special request of Hon. J. Boyd Thatcher, chairman of the Executive Committee on Awards, he took charge of the field trials of agricultural machinery and also of the tests on portable engines and boilers, as well as acting as a special judge of numerous exhibits. His duties were not fully completed when he left to take up the college work, and he has since been requested to take charge of the field trials of agricultural implements at Denver, Colorado, but was unable to do so. On invitation of Mr. Thatcher he has written the descriptive account of the exhibit of pumping machinery made by H. R. Worthington.

Professor Carpenter devoted most of his vacation to work as a judge in the Department of Machinery, where he served as chairman of the sub-groups No. 70 on fire engines and of No. 77 on clay working machinery. He served as a member on sub group 69, on engines, testing machines, hydraulic motors and pumps, in all of which classes he examined a great many exhibits. He inaugurated and took charge of such tests as could be made of fire engines Professor Carpenter also served in the Transportation Department and was a special judge on the exhibits in Car-heating and in Car-couplers. It is hoped that tests of the latter case may yet be carried out to a successful issue. Since leaving Chicago, Professor Carpenter has been repeatedly urged to return by the Fair authorities, and may do so for a short time.

Professor Ryan devoted his vacation to work as a judge in the Department of Electricity. In this department he examined with his colleagues nearly every exhibit in the department, and inaugurated and conducted to a successful issue, some exhaustive and complete tests of transformers. In the department of electricity a large number of successful tests were conducted and none were of more value than those made by Professor Ryan.

Professor Durand visited the Fair and made a thorough examination of the marine and engineering exhibits. He also attended and took part in the engineering congress.

Professor Barr devoted considerable time to an examination of the exhibits at the Fair and conducted two engine tests, one at Washington, D. C., and the other in Canada.

Mr. Geo. B. Preston, instructor, had charge of the testing machines of the government exhibit and made numerous tests of material for exhibitors. Mr. Preston's work was of a high order

and has met with the highest commendation, and it is believed will be of benefit to the University.

Mr. A. H. Eldridge, instructor, had charge of one of the large Corliss engines in Machinery Hall, and received many compliments from the authorities for the condition in which he kept his engine. His article on the design of Corliss Valve Gearing, which appeared in the SIBLEY JOURNAL last year, has been highly spoken of among the engineering profession. It has been reprinted in *Power*.

CORNELL has just completed the first quarter century of her existence. The occasion was appropriately celebrated by exercises consisting of a reception in the Library building on Friday evening, October 6, and addresses and a dinner held on the following day. Hon. Chauncey M. Depew, the orator of the occasion, delivered an address of exceeding interest, not only to every Cornellian, but to every person interested in higher education, and to everyone possessed of an admiration for clear foresight, business ability, indomitable courage, and broad-minded philanthropy, as exemplified in the character of Ezra Cornell. Addresses were also made by Hon. Stewart L. Woodford, Rev. Anson J. Upson, Chancellor of the University of the State of New York, Prof. G. C. Caldwell for the faculty, and Hon. Joseph C. Hendrix for the alumni. A new departure for America was inaugurated in the presentation of a Commemoratory Volume to Prof. Burt G. Wilder, on behalf of his former students, by Dr. Theobald Smith, '81, and of a similar Volume to the University, by Prof. Ernest W. Huffcut. The first-mentioned book consisted of contributions on various scientific subjects by sixteen of the former pupils of Dr. Wilder; while the last-mentioned one consisted of a collection of matter pertaining to the history of Cornell University. The exercises, although continuing for over three hours, held the close attention of the entire audience throughout. Immediately after the close of the exercises in the Library, the guests, University officers, and alumni proceeded to the armory, where dinner was served, followed by speeches from many of the prominent men present. On Sunday, October 8, the Sage Chapel sermon was preached in the armory, by the Rt. Rev. W. C. Doane, D.D., L.L.D.

Although a more detailed account of these most appropriate and interesting exercises, connected with the celebration of young Cornell's twenty-fifth birthday, would be out of place in these

pages, still it is only fitting that we should note the passing of so memorable an occasion. In twenty-five years the devoted perseverance of the founder and his associates, aided by the solid business principles of the trustees and the faithful work of the faculty, have brought the struggling college through the innumerable difficulties which beset her way, and have placed her among the foremost of America's institutions of learning. The side of the University represented by this Journal, Sibley College, stands second to none in the country as a technical school. In some lines the material equipment is unequalled by that of any other similar school in the world. The number of students registered in the college at the present time is nearly six hundred. The number of graduates, in the class of '93, including those taking advanced degrees, was over one hundred, the largest graduating class in Engineering, in the country. The requirements for admission are gradually being raised and the curriculum is constantly being changed to exclude all except the higher lines of work belonging exclusively to the professional education of the engineer.

AERONAUTICS or Aerial Navigation is a subject, which, although for many centuries an interesting one to man, has only of late been engaging the minds of scientific investigators. Owing to the widespread ideas concerning the impossibility of any commercial or otherwise valuable application that could be made of such researches, the attention of the general public is only just being called to the work that has been done and is now going on in this field. It is true that the difficulties of a mechanical nature that beset the inventor of a machine intended to navigate in the air are very serious, but now that the place formerly occupied almost entirely by imaginative inventors and "cranks," is being filled by scientific and practical men, it is quite probable that even if we do not arrive at a solution of the problem at once, still we may obtain knowledge of this much-vexed question, that in the future will lead to practical results.

Among other congresses held in Chicago during the past summer, was the Conference on Aerial Navigation. Papers were presented by prominent engineers and scientists of this and other countries, upon all subjects having a direct bearing upon the question in hand; the flight of birds, the behavior of air-currents the construction and operation of balloons and aerophanes, and many other topics of a similar nature, being considered. *Aero-*

nautics is the title of a new monthly review, pnblished by the *American Engineer and Railroad Journal*, devoted to the publication of all matter connected with aerial navigation, but especially to the printing of the proceedings of the above mentioned conference and the papers there presented. The effect of this review in bringing such literature before the eyes of the engineering world will undoubtedly be advantageous in creating a much wider interest in Aeronautics.

DURING the past summer the shops have not been idle. Work on the Sibley engine has been steadily progressing, all detail work being now finished. The patterns for the cylinders have been sent to the foundry and as soon as the castings are ready they will be fitted and placed in position.

The Gordon Pumps too, are nearly completed. It will be remembered that these pumps, or more properly Water Pressure Pumping Engines, are duplicates of the ones now in operation at Triphammer Falls. The task of fitting up the castings which were sent from Hamilton, Ohio, has been especially difficult as correct working drawings could not be obtained.

The Mechanical Laboratory has seen a number of changes in the past summer. The removal of the University Heating Plant to its new station back of the Armory has left much needed room in the boiler house.

The department of Experimental Engineering now has entire control over the boiler house and the 300 horse power plant which it contains, thus making possible some important laboratory practice in boiler testing.

A new machine for testing indicator springs has replaced the old one in the junior laboratory. It was designed by Professor Carpenter and aside from its superior compactness, furnishes a means of making a direct comparison of the steam pressure per square inch as measured by a balanced scale beam, and of the same pressure as measured by the indicator spring.

CRANK SHAFTS.

—It is said that there is now being built by the Messrs Dubbs, of Glascow, Scotland, an express locomotive of 2000 horse-power, intended to run at the enormous speed of 100 miles per hour. It is triple expansion, its cylinders being respectively forty, twenty-eight, and eighteen inches in diameter, and its stroke being

thirty inches. The boiler is believed to be the largest in existence and is designed to run at 200 pounds steam pressure. The distance between Glascow and London, 500 miles, is to be covered in six hours.

—The true valuation of property in the United States increased $20,000,000,000 in the ten years between 1880 and 1890; the capital invested in manufactures in 1890 was $4,600,000,000, one and two-thirds times as much as in 1880; $500,000,000 more was paid in wages to the employes of manufacturing establishments in 1890 than in 1880; more than four times as much steel was manufactured in 1890 as in 1880; the product of our mines and quarries for 1890 was almost twice that of 1880; thirty railroads which hauled 96,000,000 tons of freight in 1880, moved nearly 263,000,000 tons in 1890; the capital invested in railroads increased $5,000,000,000 in the same ten years; in 1880 electricity as applied for power was a new thing, to-day over $800,000,000 capital is invested in all branches of the industry.

—The Parsons Steam Turbine, in the hands of Professor A. B. W. Kennedy, has recently given extraordinarily economical results. With a steam-pressure of 95 to 99 pounds, and a vacuum of about 14 inches, developing 37 to 165 horse-power, the weight of steam demanded ranged from 33 to 20.3 pounds, per *electrical* horse power, per hour. This is probably not above eighteen pounds per *indicated* horse-power, and places this machine beside the best classes of engines of the more usual types. The report of this wonderful and unanticipated performance is given in *London Engineering*, July 28th, 1893.

—There is to be held in each of the cities of Amtwerp and Brussels, distant from each other about twenty-five miles, an international exhibition, simultaneously, in the year 1895. This fact has caused the proposal to build, between those two cities, an electric railway, over which the whole trip shall be made in a little over twenty minutes, at the rate of 112 miles an hour. Trains consisting of two cars each are to be run every fifteen minutes. Mr. Flamache, the promoter, thinks that the rapid revolution of the wheels will tend to prevent derailment.

—Dr. Thurston has recently sent to all of the prominent exhibitors in the line of engineering, at the World's Fair, a circular letter, in which he points out the advantage of placing objects of interest in the museum of Sibley College. The great mass of exhibitions now in Chicago must soon be disposed of by their owners. Often the best thing that can be done with portions of these immense collections, will be to present them to some tech-

nical school or museum, where they will be of lasting benefit to the young men preparing to enter the field of engineering. It will be a great advantage to the donors to have the coming generation of engineers familiar with their peculiar forms of apparatus. Professor Thurston asks that, in such cases, the exhibitor, before deciding where to send his collections, shall take cognizance of the advantages offered by Sibley College for this purpose. He describes very briefly the equipment and aims of this department of Cornell University, and states its readiness to receive additions to its already large and valuable collections.

PERSONALS.

'90.

P. M. Chamberlain is an assistant professor of mechanical engineering, at the Michigan Agricultural College at Lansing.

'91.

Paul K. Browd is with the Solway Process Co. Syracuse, N. Y.

Louis W. Emerick is employed by the Electric Supply Co. of Syracuse, N. Y.

Frank A. Barton, who will be remembered as a former Colonel of the Cornell Regiment, took the examinations for the army and is now 2nd Lieutenant in the 10th Cavalry stationed at Fort Custer, Montana.

'92.

Henry Floy, P. G., had charge of the Westinghouse Co's exhibit and plant at Chicago this summer.

J. C. McMynn has a position as consulting engineer with R. H. Hunt & Co., Rookery Building, Chicago.

Nelson Macy, of glee club fame, is now employed by the Illinois Branch of Rathburn, Laid & Co. Albany, N. Y.

Carl B. Auel is with the Westinghouse Electric Co., Pittsburgh, Pa. At present he is stationed at the large switchboard in Machinery Hall, at the World's Fair.

'93.

Alvan H. Alberger is in Buffalo with the Buffalo Pump Works.

Frederick W. Kelly is with the Electric Car Heating Co. Albany, N. Y.

Guido H. Marx has a position with the Gleason Tool Works of Rochester, N. Y.

Carl M. Green took the examination for assistant engineer of the Revenue Marine Service, and passed second in the list.

THE SIBLEY JOURNAL OF ENGINEERING.

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IN CORNELL UNIVERSITY

"The leading object shall be, without excluding other scientific and classical studies, and including military tactics, to teach such branches of learning as are related to Agriculture and the Mechanic Arts, in such manner as the legislatures of the States may respectively prescribe, in order to promote the liberal and practical education of Industrial Classes in the several pursuits and professions in life."—[An act donating public lands to the several States and Territories which may provide Colleges for the benefit of Agriculture and the Mechanic Arts, July 6, 1862.]

GRAPHICAL METHOD OF COMPUTING THE STEAM CONSUMPTION PER INDICATED HORSE POWER PER HOUR FROM THE DIAGRAM.

BY R. C. CARPENTER.

The ordinary standard by which the economy of the steam engine is measured is the actual weight of dry steam consumed in one hour of time for each indicated horse power developed. This quantity, which we term the actual *water-rate*, can only be ascertained by the tedious processes of an engine test.

The indicator diagram shows the pressure exerted on each square inch of the piston at any point of the stroke. Steam tables give the weight per cubic foot of steam corresponding to any pressure. If then the volumes filled with steam in a given time were known, by aid of indicator diagrams and steam tables the weight of steam could be computed. The results obtained by such a computation would agree with the actual consumption were the engine worked with steam which always maintained the *dry* and *saturated* condition. A computation of the weight of steam shown by the indicator diagram per indicated horse power per hour, termed here the *diagram water-rate*, forms not only an interesting study, but is of value in pointing out probable losses which occur due to internal condensation and subsequent gains due to re-evaporation. It also may perhaps be made to

H. T. Cory

furnish a standard by means of which the performance of an engine may be judged, although there are many limitations, some of which will be pointed out later, that might modify any conclusions drawn from study of the diagram only. It is no doubt true that a reasonable standard could be established for the diagram water consumption per I. H. P. per hour by means of which the performance could be judged.

As a reasonable standard I would suggest that the diagram *water-rates* of various classes of engines, should not exceed the following figures :

NON CONDENSING.

Small Throttling Engine,	gauge pressure	60 to 80,	34 to 30	pounds.
Automatic Engine,	" "	80 to 100,	30 to 22	"
Corliss Simple,	" "	80 to 100,	22 to 20	"
Compound Automatic,	" "	100 to 125,	20 to 18	"

CONDENSING ENGINE.

Corliss Simple,	gauge pressure	60 to 100,	19 to 17	"
Compound Automatic,	" "	80 to 100,	15 to 13.5	"
Corliss Compound,	" "	80 to 125,	14 to 11	"
Triple Expansion,	" "	100 to 150,	12 to 10	"

The smaller numbers in each case corresponding to the higher steam pressures.

The steam consumption as shown by the diagram must in every case be considerably less than the true consumption, since computation from the diagram can give only the weight of dry steam required to fill the cylinder. This is much less than the actual steam used, since the action of the cylinder walls tends to condense much of the original steam, so that a certain part exists in the cylinder in the form of water and cannot be determined from an examination of the indicator diagram. This condensed water is often a large percentage of the weight of the condensed steam, usually being from 25 to 45 per cent. at cut-off and 14 to 30 per cent. at release. The volume occupied by this water is, however, very small, since the weight of water is many times that of an equal volume of steam ; thus at 80 pound gauge pressure one pound of steam occupies 281 times as much space as one pound of water. This would indicate that 40 per cent. of water by weight is equivalent to $\frac{14}{100}$ of one per cent. by volume, which does not seem a great quantity.

The fact that the steam is much more moist at cut-off than at release would indicate that we were to expect the steam con-

sumption as shown from the diagram to approach more nearly that actually obtained by measurement of the feed water when measured at release than when measured at cut-off.

The difference in amount shown at cut-off and at release is usually quite considerable, and may be considered proof positive of the re-evaporation which takes place in the cylinder during expansion. It is, indeed, quite an accurate measure of the amount of this re-evaporation. The quality of the steam, which is here taken to be the percentage of dry steam, is very nearly the quotient obtained by dividing the weight of steam per indicated horse power per hour as shown by the diagram, by the actual weight used as obtained by measurement of the feed water. These are very interesting quantities to obtain. From the considerations it would seem that the actual steam consumption of an engine ought to be from 1.7 to 1.4 times that shown by the diagram at cut-off, and from 1.4 to 1.2 times that from the diagram at release. If the actual consumption is very much in excess of the limits as given above, the engine should be carefully examined for leaks in the valves and piston.

The leakage of steam past the valves or piston, unless excessive, does not affect the form of the diagram in any appreciable manner, and hence will not be accounted for in any computation made from it.

The principle involved in the method of computing the steam used by the indicator diagram is quite simple, although the application is quite tedious, as it involves a number of calculations.

An analytic method for such computation is published in *Experimental Engineering* page 499, which is believed to be original with the author. The analytic and graphic methods which are given here were first published in *Power*, September and October, 1893, and are believed to present a novel treatment of the subject and a new and convenient method of obtaining the diagram *water-rate*.

THE ANALYTIC METHOD.

This method is as follows: Find the number of cubic feet of steam in the cylinder to cut-off or release, or any other point if required, including the clearance spaces, multiply this by the weight of steam required to fill one cubic foot, having a pressure equal to that shown by the diagram at the required point, and obtained from a steam table. Diminish this by the weight of steam required to fill the clearance space at end of

compression, since this steam is not exhausted from the engine. The results give the weight of steam from the diagram for one stroke. This multiplied by the number of strokes per hour and divided by the indicated horse-power gives the results sought.

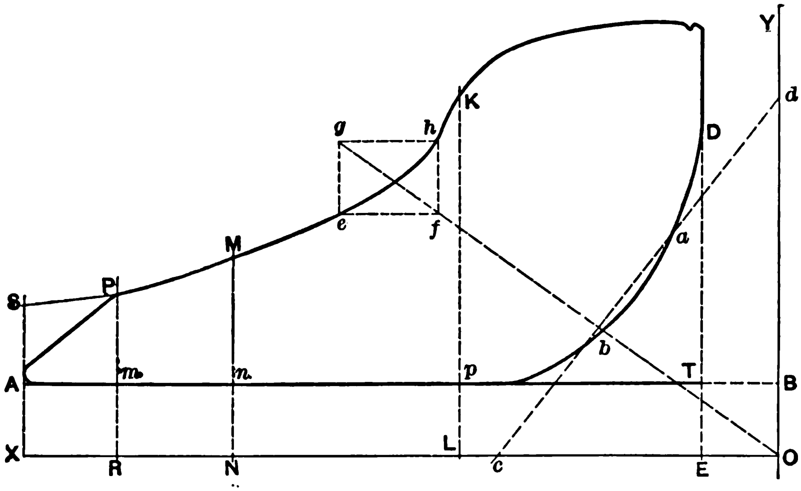


FIG. 1.—*Steam Consumption from Indicator Card.*

An example will make this clear: Fig. 1 is the reproduction of a diagram taken from an automatic engine (crank end), with 40 spring. Size of engine, 12 by 14; piston rod diameter, 1½ inches; area of head, less piston rod, 111.2 inches, or 0.772 square foot. Length of stroke, 14 inches, or 1.166 feet. Volume of piston displacement, 0.902 cubic feet. Clearance measured 8.75 per cent., or 0.079 cubic foot. Had the clearance not been known it might have been obtained approximately by drawing a straight line, *cbad*, across the compression curve, first having drawn *OX* parallel to the atmospheric line and 14.7 pounds below. Measure from *a* the distance *ad*, equal to *cb*, and draw *YO* perpendicular to *OX* through *d*, then will *TB* divided by *AT* be the percentage of clearance. The clearance may also be found from the expansion line by constructing a rectangle *efhg* and drawing a diagonal *gf* to intersect the line *XO*. This will give the point *O*, and by erecting a perpendicular to *XO* we obtain the clearance line *OY*.

Both these methods for finding the clearance require that the expansion and compression curves be hyperbolas. With good diagrams I have found the method to be usually very accurate, and to give results which check substantially as well as those

shown in Fig. 1, in which case all these methods give the same clearance line.

The pressures are best measured from a vacuum line, which is the line *OX*, drawn 14.7 pounds below the atmospheric line as explained. For instance, suppose that we wished to find the weight of steam when the piston is at *K*, *M*, and *P*. The absolute pressure is measured from the line *OX* with a 40 scale; the weight of a cubic foot of steam is taken from a steam table, the one used in this case being the one in *Experimental Engineering*.

Tabulating these various results to economize space, we have the compilation shown in Table I.

TABLE I.

COMPILATION OF STEAM CONSUMPTION PER INDICATED HORSE-POWER FROM DIAGRAM.		Point taken slightly beyond cut-off. See Fig. 1 at *K*.	Intermediate Point on expansion curve. *M* in Fig 1.	At Release *P* Fig. 1.
Absolute Pressure from Diagram	. .	75	41	35
Wt. of cu. ft. Steam, Steam Table	(w)	0.1756	0.0995	0.858
Per cent. of Stroke at Point	.	35.7	69.2	86.2
Cu. ft. of Steam at Point	(b)	0.402	0.704	0.854
Cu. ft. of Steam in Clearance	(c)	0.079	0.079	0.079
Wt. of cu. ft. of Steam, Pressure. *E D*	(w')	0.1424	0.1424	0.1424
Weight of Steam per Stroke. $(w \times b)-(c) \times (w')=$	E	0.0585	0.058	0.0623
No. of Strokes per hour	N	14700	14700	14700
I. H. P. per hour	I	38.1	38.1	38.1
Water per I. H. P. per hr. $N \times E \div I$	K	22.6	22.3	23.8
Actual water by test	. .	31.0	31.0	31.0
Quality of Steam	. .	0.73	72.0	76.5
Per cent. of Moisture	. .	0.27	28	23.5

This calculation can be very much abridged, since in the arithmetical process above described there are many common factors which may be cancelled out.

If we put these very same steps in algebraic language, these common factors can be struck out and the results expressed by a very simple rule.

Thus, represent the mean effective pressure by p, the length of stroke in feet by l, the area of piston in square inches by a, and in square feet by $\frac{a}{144}$. Denote the percentage of clearance to the stroke by c, the percentage of stroke at point when water rate is to be computed by b, number of strokes per minute by n, the

number per hour by $60n$, the weight of a cubic foot of steam having a pressure as shown by the diagram corresponding to that at the point where water rate is required by w, and that corresponding to pressure at end of compression by w^1.

We shall have the following equations:

Number of cubic feet per stroke,

$$l\left(\frac{b+c}{100}\right)\frac{a}{144}. \qquad (1)$$

Corresponding weight of steam per stroke,

$$l\left(\frac{b+c}{100}\right)\frac{a}{144}w \qquad (2)$$

Volume of clearance,

$$\frac{lca}{14{,}400} \qquad (3)$$

Weight of steam in clearance,

$$\frac{lcaw^1}{14{,}400} \qquad (4)$$

Total weight of steam per stroke,

$$l\left(\frac{b+c}{100}\right)\frac{wa}{144}-\frac{lcaw^1}{144}= \qquad (5)$$

$$\frac{la}{14{,}400}\left[(b+c)\,w-cw^1\right] \qquad (5)$$

Total weight of steam from diagram per hour,

$$\frac{60nla}{14{,}400}\left[(b+c)\,w-cw^1\right] \qquad (6)$$

The indicated horse-power is $plan$ divided by 33,000. Hence by division the steam consumption per indicated horse-power per hour is

$$\frac{\frac{60nla}{14{,}400}\left[(b+c)\,w-cw^1\right]}{\frac{plan}{33{,}000}}= \qquad (7)$$

$$\frac{137.50}{p}\left[(b+c)\,w-cw^1\right] \qquad (7)$$

Changing the formula to a practical rule, we have the following: To find the water rate from the indicator diagram at any point in the stroke.

RULE.—*To the percentage of the entire stroke which has been completed by the piston as the point under consideration, add the percentage of clearance. Multiply this result by the weight of a cubic foot of steam, having a pressure of that at the required point.*

*Subtract from this the product of percentage of clearance multiplied by weight of a cubic foot of steam having a pressure equal to that at the end of the compression. Multiply this result by 137.50 divided by the mean effective pressure.** *The product will be the result sought.*

With this rule the calculations become very simple indeed. Taking the diagram Fig. 1.

The clearance c equals 8.75 per cent.

In percentage of the stroke, $p\,T$ corresponding to point K is 35.7.

In percentage of stroke $n\,T$ corresponding to point M is 69.2.

In percentage of stroke, $m\,T$ corresponding to point P is 86.2.

The pressure measured from vacuum line to these parts are as follows: KL, 75 pounds; MN, 41 pounds; and PR, 35 pounds. The respective weights per cubic foot corresponding to these pressures by the steam tables are:

For point K, 0.1756 pound per cubic foot.

For point M, 0.0995 pound per cubic feet.

For point P, 0.0858 pound per cubic foot.

For point D, 0.1424 pound per cubic foot.

The mean effective pressure of the diagram is 40 pounds. The water rate for each case would then be as follows:

First, at point R

$$\frac{137.5}{40}\Big[(35.7+8.75)(.1756)-$$

$$(8.75)(.1424)\Big]=\frac{137.5}{40}(7.8-1.25)=22.5$$

Second, at point N

$$\frac{137.5}{40}\Big[(69.2+8.75)\,.0995-(8.78)\,.1424\Big]$$

$$=\frac{137.5}{40}(7.75-1.25)=22.3$$

Third at point P

$$\frac{137.5}{40}\Big[(86.2+8.75)\,.0858-1.25\Big]=$$

$$\frac{137.5}{40}(8.22-1.25)=23.8$$

Since 31 pounds of water was actually used per indicated horsepower, the quality at these points would be approximately

* For compound or triple expansion engines read: divided by the equivalent mean effective pressure, on the supposition that all work is done in one cylinder.

NOTE.—This method only applies to points in the expansion curve or between cut-off and release.

Cut-off point K, 72.5 per cent.
Intermediate M, 72.0 per cent.
Release point P, 76.5 per cent.

This would indicate that for this case the percentage of moisture in the steam at cut-off was 27.50, but at release this had been reduced to 23.5, due to re-evaporation during expansion. The results shown by the diagram at release multiplied by 1.3 give the actual results obtained.

The beneficial effect of compression in reducing the water consumption of an engine is very clearly shown by formula (7).

If the compression is carried to such a point that it produces a pressure equal to that at the point under consideration, the weight of steam per cubic foot is equal, and $w = w^1$. In this case the effect of clearance entirely disappears and the formula becomes

$$\frac{137.5}{p} (b\,w) \tag{8}$$

In case of no compression, w^1 becomes zero, and the water-rate equals,

$$\frac{137.5}{p} [(b + c)\,w]$$

The rule and formulæ already given for simple engines are made applicable to compound or triple engines by considering the value of the mean effective pressure as that which would have existed had the work all been done in one cylinder. Although either cylinder may be used, the low pressure cylinder is commonly taken, in which case the results are the same as those obtained from the combined diagram.

If the mean effective pressure actually existing in each cylinder, and the diameter and stroke of each piston, are known, the equivalent mean effective pressure is readily computed, from the well-known fact that as the volume of piston displacement is increased, the mean effective pressure required to develop a given amount of work is diminished. Thus, for example, to find that mean effective pressure required in the low pressure cylinder to be the equivalent of that actually found in both cylinders, consider a compound engine in which the high pressure cylinder is 9 inches in diameter with 18 inches stroke, and the low pressure 16 inches in diameter with 24 inches stroke: we should then have

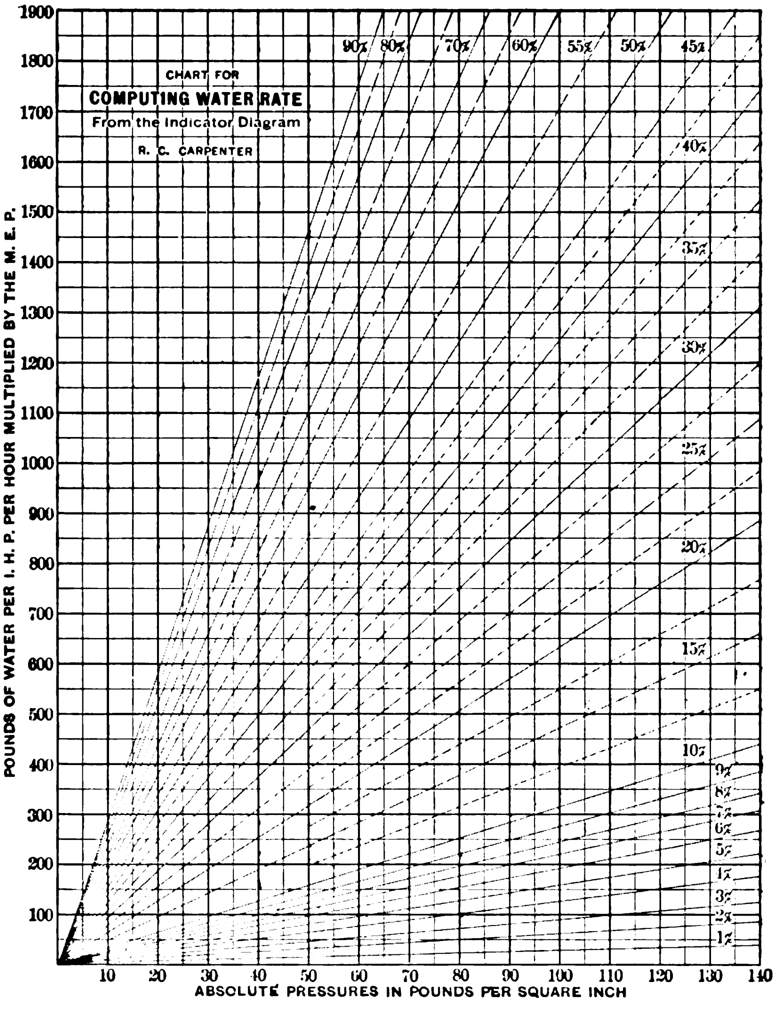
Area of piston, sq. in.,	H. P., 63.617 ;	L. P.,	201.06
Stroke, inches	" 18	"	24
Vol. piston displacem't cu. in.	1145.1	"	4825.4
Ratio of volumes	1		4.2

If the actual mean effective pressure found was 40 in the high pressure and 8 in the low, the equivalent mean effective pressure, in order that the same work may be done in the low pressure, would be 40 divided by 4.2 (which is equal to 9.51) added to that found in the low pressure, making the equivalent mean effective pressure ($9.51 + 8 =$) 17.51 in order that the work done in low pressure cylinder should equal the entire work of the engine. Using this value of pressure in formula (7), and taking the measurements from the low pressure diagram, as explained for the case of a simple engine, the water rate is readily computed.

In some instances it might be desired to find the equivalent mean effective pressure for the total work done in the high pressure cylinders, and thus refer computations to that cylinder instead of the other. In this case the mean effective pressure of the low pressure cylinder would be multiplied by the ratio of the volumes, and added to that for the high. For the example stated we should have $8 \times 4.2 = 33.6 + 40 = 73.6$ as the equivalent mean effective pressure in this case. All measurements would now be taken from the diagram of the high pressure cylinder. These results will not, of course, be the same, since the cylinder condensation is quite different in the different cylinders. The results reduced to the high pressure cylinder are generally higher than those reduced to the low.

For the sake of uniformity it is better to perform computation for the equivalent mean effective pressure for the whole work in the low pressure cylinder.

In the case of a triple expansion engine the same process of computation is required to find the equivalent mean effective pressure. The mean effective pressure of the high pressure cylinder as found from the diagram must be divided by the ratio of volumes of low to high, and that of the intermediate by the ratio of volumes of low to intermediate. The sum of all these quantities will give the equivalent mean effective pressure. The formula and method of using will be the same as for a simple engine. An application to an actual set of diagrams will, no doubt, make the matter more clear.



The diagrams shown in Fig. 2 were taken from an automatic compound engine run non-condensing. The diameters of the cylinders were 7.95 and 14 inches respectively; the stroke was 20 inches. The ratio of volume of piston displacement was 1 to 3.11. Spring used with the high pressure diagram was 60; with low pressure diagram, 20. The mean effective pressure of the high pressure diagram is 13; clearance in high pressure cylinder, 16.1 per cent.; in low pressure cylinder, 13.1 per cent. The equivalent mean effective pressure, provided the work was done

in the low pressure cylinder, is 60.7 divided by 3.11, which equals 19.5. Added to 13.0 this gives 32.5. The cut-off in the low

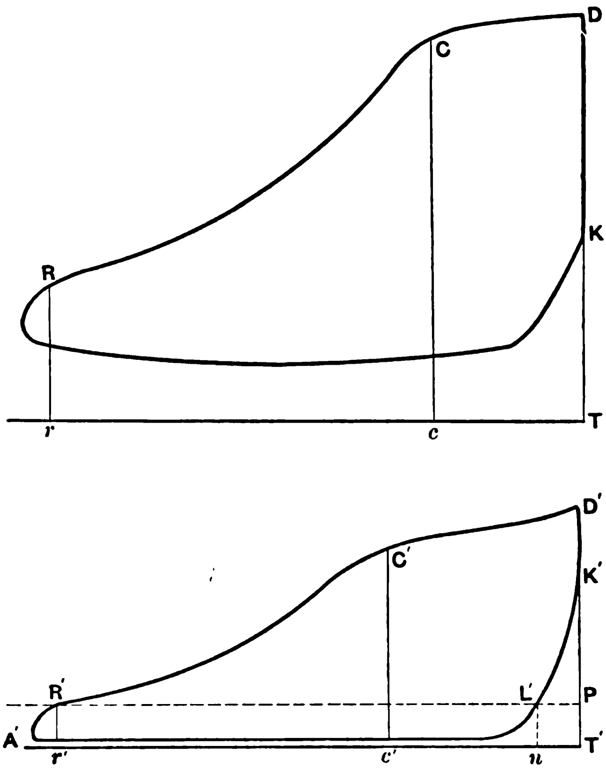


FIG. 2.

pressure takes place at 33.5 per cent. of stroke, the release at 95.5 per cent. The water rate by formula (7) becomes for cut-off.

$$\frac{137.5}{32.5}\left[(33.5 + 13.1)\, w - 13.1\, w^1 \right]$$

w being the weight of a cubic foot steam at release pressure, and w^1 the weight at the end of compression. This pressure is measured from the diagram, and 14.5 added to reduce it to absolute pressure (14.7 pounds would ordinarily be used, but in this case the barometer reading corresponding to 14.5 pounds). The weight is then taken from a steam table.

For the above cases the pressures from the diagrams are respectfully 20.5 and 16 above atmosphere. The absolute pressures

for this particular test, which was performed when the barometer reading was equivalent to 14.5 pounds, are 35 and 30.5. The corresponding weights of a cubic foot of steam are .0858 pounds and .075 pounds. The substitution of these values gives as a result

$$\frac{137.5}{32.5}\left[(46.6)\ .0858 - (13.1)\ .075\right] =$$

$$\frac{137.5}{32.5}(4.01 - .98) = 12.7 \text{ lbs.}$$

The multiplication was performed on a ten-inch slide rule, and should be accurate to about one-fourth of one per cent. At least the corresponding absolute pressure is 18.5 pounds, and the weight of a cubic foot .0471 pounds. The corresponding water rate from the diagram is for this position.

$$\frac{137.5}{32.5}\left[(95.5 + 13.1)\ .0471 - .98\right] =$$

$$\frac{137.5}{32.5}\left[5.12 - .98\right] = 17.5$$

If the clearance were entirely neglected, we would have, as in formula (8)

$$\frac{137.5(bw)}{p}$$

This becomes, for cut-off

$$\frac{137.5}{32.5}\left[33.5\ (.0858)\right] = 12.2$$

And for release,

$$\frac{137.5}{32.5}\left[95.5\ (.0471)\right] = 19$$

For cut-off this result is nearly the same as the correct one; since the pressure at the end of compression is nearly equal to that at cut-off the correction is small. For the water-rate computed at release the error is large, since the pressure at the end of compression is much greater than that at release, consequently if no correction be made for clearance, considerable error will result. A method of correcting this error is as follows: by projecting the horizontal line $R'L'P$ through release, we see that when the compression pressure is equal to that of release, the volume of steam caught in compression is $L'P$. As volume occupied by steam is nearly inversely as the pressure, the correct water rate should be given very nearly by simply multiplying this result by the ratio of $R'L'$ to $R'P$. This ratio is .926. 19 multiplied by .926 gives

17.6 as the water rate, a result which is very little in error. The actual water consumption as given by the test was 22.6 pounds of water per indicated horse-power per hour. Consequently the water rate from the diagram, increased by 28 per cent., will give the actual water consumption of the engine.

TABLE II.—COMPUTATION OF WATER PER I. H. P. PER HOUR FROM DIAGRAMS OF A TRIPLE EXPANSION ENGINE.

In this computation volumes of head ends of each cylinder and of crank ends were compared. Although both ends of high pressure cylinder were called one, in the computation above they are not equal, the area of head end of piston containing 615.7 sq. in., that of crank end containing 590.6 sq. in.	COMPUTATION BASED ON WORK BEING ALL DONE IN					
	HIGH.		INTERMEDIATE.		LOW.	
	Head.	Crank.	Head.	Crank.	Head.	Crank.
Relative vol. of cyl. .	1	1	2.95	3.01	6.95	7.01
" " " .	0.34	0.332	1	1	2.36	2.35
M. E. P., actual . . .	46.8	49.35	15.43	14.296	8.8	8.58
Equiv. M. E. P. were w'k all done in 1 cyl	153.5	152.75	52.08	51.1	22.03	21.6
Abs. press. at cut-off	135.9	135.3	41.5	41.5	13.3	13.2
" " release .	47.6	49.8	15.3	14.34	5.44	5.3
" " end com	115.0	95.0	28.5	28.5	13.5	10.5
WT. IN LBS. OF 1 CU. FT. FROM TABLES.						
At cut-off . . . . (w)	0.3075	0.3062	0.1006	.1006	.0345	.0343
At release . . . . (w)	.1141	.1195	.0395	.0370	.0149	.0145
At end of comp. (w')	.2627	.2194	.0706	.0706	.0349	.0276
Per ct. cut-off; stroke =100 . . . . . (b)	35.526	36.264	34.62	32.31	39.59	38.56
Per ct. clear.; stroke =100 . . . . . . (c)	1.4	1.4	1.5	1.5	0.77	0.77
Per cent. release; stroke =100 . . (b)	100	100	100	100	100	100
COMPUTATION BY FORMULA (7) GIVES						
Water rate at cut-off .	9.87	9.80	9.27	8.92	8.42	8.41
Water rate at release .	10.24	10.67	10.28	10.12	9.25	9.22
Av. for each case .	10.45		10.2		9.235	

The computations in Table II are very complete, and will no doubt be of interest, as they were made in connection with a test of the triple expansion pumping engine at North Point Station, Milwaukee. A set of diagrams is shown in Fig. 3, but the measurements

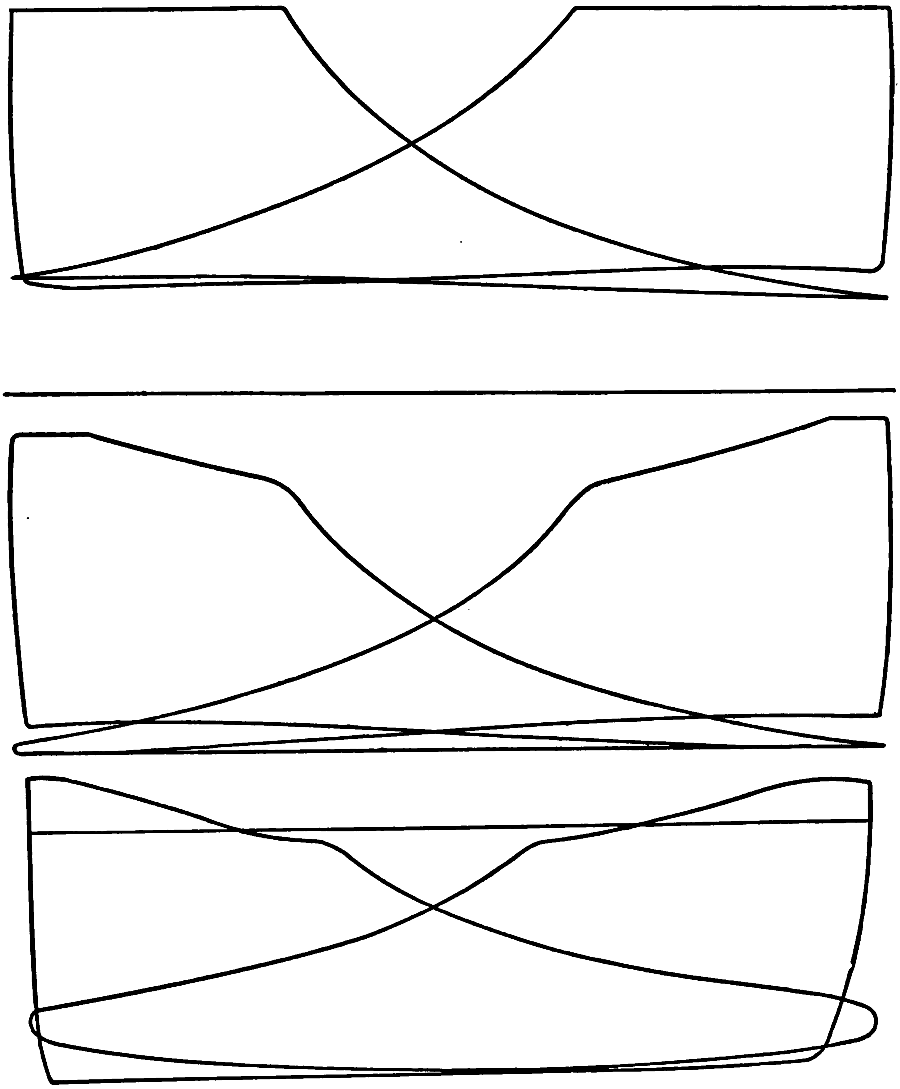


FIG. 3.—*Diagrams from North Point Engines.*

given in Table II were taken from a large number of diagrams, and so may differ somewhat from the results obtained by measurement of the diagrams in the figure. The dimensions of the engine were as follows: diameters, 28, 48, and 74 inches; stroke, 60 inches; two piston rods in each cylinder, each with a diameter

of 4 inches. The clearances in per cent. of stroke are as follows: high pressure, 1.4; intermediate, 1.5; low .77. The water rate was computed, as explained, on the supposition that the entire work was done in any one of the cylinders, although for purposes of comparison, as before mentioned, that from the low pressure cylinder only should be used. This water rate was 9.235 pounds, the actual water rate found on the test was 11.678 pounds, or 26 per cent. above that indicated by the diagram.

GRAPHICAL COMPUTATION.

The computation of water-rate from an indicator diagram can be performed by means of the accompanying chart. In this chart the abscissa are the absolute steam pressures at the points under consideration, the ordinates are the products of mean effective pressure and pounds of water per indicated horse power per hour. To use the diagram, one must know the absolute pressure at the point under consideration, the per cent. of the stroke completed, the per cent. of clearance, the mean effective pressure, and the pressure at the end of compression. This will be rendered clear by one example. Thus, take the case represented by Fig. I, and determine the water rate at the point *K*. We have by measurement, absolute pressure, 75 pounds at *K*, 60 pounds at *D*; per cent. of stroke completed at *K*, 35.7; clearance, 8.75; mean effective pressure, 40.

To use the diagram, follow along the horizontal line until you reach the pressure 75, then pass in a vertical line until the diagonal corresponding to $(35.7 + 8.75) = 44.45$ is found. This will be found by interpolation between the diagonals for 45 and 47.5. Then pass in a horizontal direction and read the result at the margin to the left: this is 1,070. To correct for clearance, pass to 60 pounds pressure on the horizontal line, then in a vertical direction to the diagonal corresponding to 8.75, then pass to the left and read 170. From 1,070 take 170; the result is 900. This divided by the mean effective pressure, 40, gives the water rate 22.5, the same as in example 1.

The chart contains all the data for this calculation not found on the indicator diagram, and by its aid the water rate can be computed without consulting steam tables. The method of using the diagram is fully explained in the preceding example. It consists in passing in a horizontal direction a distance proportional to the absolute pressure as marked on the base line, thence in a vertical line a distance determined by the diagonal lines and

corresponding to the percentage of stroke increased by the percentage of clearance. Read the first partial result on the left hand margin. To correct this for steam retained in clearance, use absolute pressure at the end of compression as before, pass in a vertical direction to the diagonal which corresponds to the per cent. of clearance; read the second partial result on the left margin; divide the difference of these two partial results by the mean effective pressure, and the quotient is the water rate or pounds of steam per indicated horse power per hour, as shown by the indicator diagram.

I think with little practice a person can soon become proficient in the use of this chart.

NOTE.—We are indebted to *Power* for the cuts to the above article.

A PLANIMETER FOR AVERAGING RADIAL ORDINATES.

BY W. F. DURAND.

In engineering work it sometimes becomes desirable to be able to obtain from polar or radial diagrams the mean radial ordinate.

With diagrams plotted on rectangular coördinates, the corresponding problem is solved by finding the area between the curve and the axis of x, and dividing this by the length of the axis concerned.

We will first point out the reasons which prevent a similar procedure for the polar diagram.

Suppose such diagram plotted upon a base circle of radius a. Let the total radius from the origin to any point of the curve be r. Then $(r - a)$ is the corresponding ordinate, and the area for a whole revolution will be $\frac{1}{2}\int r^2 d\theta - \frac{1}{2}\int a^2 d\theta = \frac{1}{2}\int (r^2 - a^2) d\theta$.

If then we find the value of this area by planimeter or otherwise, and divide it by $\frac{1}{2}\int d\theta$ or π, the result will be the mean of the quantities $(r^2 - a^2)$. In no way from this are we able to find the mean value of $(r - a)$. Likewise if we divide by πa we shall have the mean of the quantities $\left(\frac{r^2}{a} - a\right)$. This again gives no means of finding the mean value desired.

It becomes necessary, therefore, to devise some other method for obtaining in such case the value of the mean radial ordinate. This we derive as follows:

The value of the ordinate at any given point is

$$(r-a) = \frac{(r-a)\,d\,\theta}{d\,\theta}$$

The mean value will be, therefore, equal to

$$\frac{\int(r-a)\,d\,\theta}{\int d\,\theta} = \frac{\int(r-a)\,d\,\theta}{2\pi}.$$

Somewhat differently, this result may be derived as follows:

Consider any indefinitely small portion of the curve ds. Let r be the radius to its central point, and let a circular arc with this radius be described through ds. Then $r\,d\theta$ will be the projection of ds upon this arc. *Vice versa*, the projection of ds divided by $d\theta$ will give the mean radius for the length ds. Hence for the whole curve the mean radius will be obtained by dividing the summation of these projections by the summation of the angular intervals. That is, mean radius =

$$\frac{\int r\,d\,\theta}{\int d\,\theta} = \frac{\int r\,d\,\theta}{2\pi}.$$

Hence the mean ordinate will be

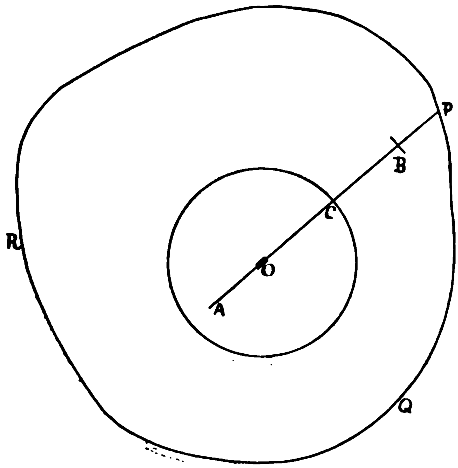
$$\frac{\int r\,d\,\theta}{2\pi} - a \text{ or } \frac{\int(r-a)\,d\,\theta}{2\pi}$$

as before. We have next to devise some form of apparatus which will enable us to realize mechanically the operations involved in the integration of $\int r\,d\,\theta$.

It is evident that if we can devise an instrument which will sum the circumferential components of the various elements ds, as above described, the problem will be solved. To this end we need some form of integrating wheel which will take cognizance of motion in angular direction only, and whose rate of revolution will vary with the radius r.

The arrangement shown in skeleton in the figure, readily suggests itself. AP is an arm carrying a tracing point at P, and an integrating wheel at B, the axis of the latter being in the line OP. O is the origin or center at which is a socket. This allows of a radial motion of the arm AP. At the same time the socket is pivoted at O, so that P has all the freedom necessary to allow it to follow any given curve. It follows that the motion of AP relative to the socket can be one of radial sliding only. Under such limitations it follows that the integrating wheel B will record simply the angular component of the movement of the point P.

Let $BP = c$ and $OP = r$. Then the radius of OB is $(r-c)$,



and we have for the motion recorded by B, corresponding to an angular movement $d\theta$, $dR = (r - c)\, d\theta$. Hence the record for an entire revolution will be

$$R = \int_0^{2\pi} (r - c)\, d\theta = \int_0^{2\pi} r\, d\theta - 2\pi c.$$

Therefore

$$\int_0^{2\pi} r\, d\theta = R + 2\pi c \text{ and } \frac{\int_0^{2\pi} r\, d\theta}{2\pi} - a = \frac{R}{2\pi} + (c - a).$$

If therefore an adjustment is provided so that the distance c may be made equal to the radius of the base circle a, we shall have simply, *average ordinate* $= \frac{R}{2\pi}$, and by appropriate graduation, the value may be read off in any unit desired.

It is evident that similar relationships hold for any fraction of a revolution, so that we may write generally :

Average ordinate for angle θ

$$= \frac{\int_0^{\theta} r\, d\theta}{\theta} - a = \frac{\textit{Record for angle } \theta}{\theta} + (c - a).$$

And if $c = a$,

$$\textit{Average ordinate for angle } \theta = \frac{\textit{Record for angle } \theta}{\theta}.$$

In this respect, the instrument differs from the ordinary polar planimeter, in which the contour traced must be closed before the record has any simple significance.

As instances where the operation of such an instrument might be of use, we may mention the derivation of the mean turning moment from a circular diagram of crank effort, and the derivation of the mean pressure or mean temperature from the diagrams as given by certain forms of recording thermometers and pressure gauges.

COMPARATIVE TEST OF HYDRAULIC RAMS.

E. T. ADAMS AND C. E. HOUGHTON.

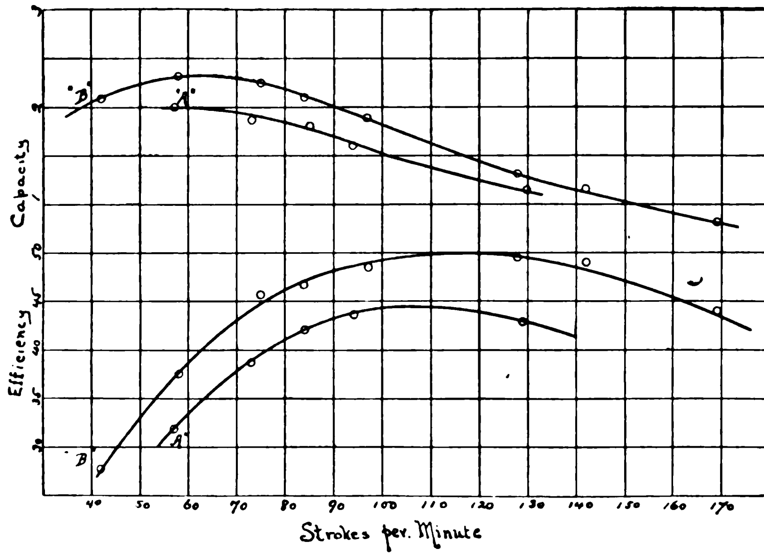
The object of the test was to determine the comparative efficiencies of two rams, having like parts, but differently arranged. The ram designated "A" has the air chamber between supply pipe and the clack valve, while in ram "B" this order is reversed, the clack valve being between the supply pipe and the air chamber.

The supply head was maintained constant by means of a tank and float valve. The water was raised to a tank having an overflow pipe through which it flowed from the tank to a barrel placed on a platform scale, and was there weighed. The waste water from the clack valve was also carefully weighed.

The ram was started and allowed to work several minutes until the flow of water from the overflow pipe leading from the receiving tank, was observed to be a maximum and uniform. The scale beam was set at a certain number of pounds and when the weight of water discharged from the clack valve was sufficient to raise the scale beam, the time was taken by one observer, and a vessel placed to catch the discharge by another. Equal care was taken in closing the test.

The length of stroke was calipered between the brass clack valve and a steel bar. Efficiency was calculated by the usual formula $E = q\,h' \div Q\,h$, where E = efficiency; q = the weight of water raised to the height h'; Q = the total weight of water; and h = static head of supply.

As is shown by the graphical log, 100 to 120 strokes gives maximum efficiency and 60 strokes per minute gives maximum capacity for both rams. Form "B" having the clack valve be-



tween the supply pipe and the air chamber is considerably more efficient and has greater capacity at all speeds than form "A."

Under average conditions, 80 strokes per minute would be the best speed for Ram B.

RECORD OF TESTS ON No. 3 RAM.—"A,"—AIR CHAMBER BETWEEN SUPPLY AND CLACK.

No. of Run.	1	2	3	4	5
Strokes per min.	57	73	84	94	129
Duration, min.	12	16	17¾	21¼	29
Supply head, ft.	4	4	4	4	4
Discharge head, ft.	21.75	21.75	21.75	21.75	21.75
Wt. of water pumped	23.85	29.8	32.6	34	33.25
" " wasted	390	390	390	390	390
" " supplied	413.85	419.8	422.6	424	423.2
Available energy	1655	1675	1680	1690	1685
Work done	517	647	707	740	725
Efficiency of ram	31.2	38.7	42	43.6	42.7
Water pumped per min.	1.99	1.86	1.84	1.6	1.15

RECORD OF TESTS ON No. 3 RAM.—"B,"—CLACK BETWEEN SUPPLY AND AIR CHAMBER.

No. of Run.	1	2	3	4	5	6	7	8
Length of stroke, ins.	0.83	0.22	0.17	0.12	0.08	0.06	0.04	0.02
Strokes per min. . .	42	58	75	84	97	128	142	169
Duration, min. . . .	10	12½	15¾	17½	20¼	30	17	21¼
Supply head, ft. . .	4	4	4	4	4	4	4	4
Discharge head, ft. .	21.75	21.75	21.75	21.75	21.75	21.75	21.75	21.75
Wt. of water pumped	20.9	28.95	35.2	36.6	38.1	38.9	19.8	17.6
" " wasted	390	390	390	390	390	390	200	200
" " supplied	410.9	418.95	425.2	426.6	428.1	428.9	219.8	217.6
Available energy . .	1644	1675	1700	1710	1721	1725	880	871
Work done	456	630	762	795	830	850	430	380
Efficiency of ram, lbs	27.7	37.6	45.5	46.7	48.5	49.4	49	44
Wat. pumped per m.	2.09	2.32	2.24	2.1	1.88	1.3	1.16	0.81

The two rams were built as stated at Professor Carpenter's suggestion, his idea being that Form "B" would prove the better. It seems probable that further changes could be made in the design that would render the ram still more efficient as a means of lifting water.

Since the only object in making this test was to compare the rams under the two different conditions described above, they were arranged in the most convenient manner, and no attempt was made to obtain conditions favorable for a higher efficiency. To this fact is due the low values for efficiency shown by our data.

THE NUMBER SEVEN IN KINEMATICS.

BY HARVEY D. WILLIAMS.

On page 561 of Kennedy's Mechanics of Machinery is illustrated a simple kinematic chain of seven links, and the author in referring to this and another seven link chain in the same work expresses a hope that some competent geometer will presently take them in hand and classify and analyze them. For the benefit of those who skip from here to the last paragraph and find the seven link chains still unclassified and unanalyzed, I will say that I am an incompetent geometor and my object, as indicated in the title, is merely to say something about the number seven.

It is well known that three links connected together by sliding pairs can form a simple closed chain, provided the motions al-

lowed by the three pairs lie in the same plane; but if four or more links are paired in a similar manner there will result more than one degree of freedom and the chain will not be closed. This is equivalent, in geometrical language, to the statement that triangles are the only plane figures which are always similar when their angles are equal each to each.

If we pass to space of three dimensions by removing the restriction that relative motions must be in the same plane, we find that three links connected by sliding pairs form a rigid framework, and four is the largest number of links that can form a simple closed chain. From this we infer that the following is also true. If two *gauche* quadrilaterals have the edges of one parallel to the edges of the other, the quadrilaterals are similar; and this is true of no other *gauche* polygon.

Thus it appears that simple links connected by sliding pairs can never form a very complex chain. But with turning and twisting pairs the case is quite different. Three links joined by twisting pairs form a simple closed chain provided the axes of the helices coincide. Three links joined together by turning pairs make a rigid frame, and four links make a simple closed chain, provided the axes of the turning pairs intersect at one point. The above cases, restricted as they are, are quite simple and they appear to be the only ones that are ever treated in text books on pure mechanism. Practically nothing has been done with chains of a more general form. We are not speaking of compound chains, which are mere combinations of simple chains, but of simple chains in which each link joins but two others and each has but one degree of freedom in relation to every other link in the chain. And the question which interests us just now is, what is the greatest number of links that can be joined together in such a chain? By searching we are unable to find a simple chain of more than seven links, but to prove that seven is the greatest number is not so easy a matter.

We have frequently used as an exercise in machine designing an English pumping engine which is very remarkable for the simplicity of its construction and the complexity of its motion. It has a piston, plunger, side valve, crank, axle, and fly-wheel, and can be designed to cut off at half or quarter stroke; and yet it contains but three moving parts or four links altogether. Three of its pairs are partially constrained, but by adding other links until each pair allows but one degree of freedom, the number of links is increased to seven.

The following is another case. Let a tetrahedron be hinged by opposite edges to two other tetrahedra, and these be similarly hinged to two more and so on, forming a continuous chain, and the tetrahedra at the two ends be hinged together thus forming a ring. Such a ring will behave in the following manner. If the number of tetrahedra is less than seven it will be a rigid frame; if the number equals seven, each tetrahedron or link will have one degree of freedom in relation to every other link in the chain, and with more than seven the motion of each link will be only partially constrained.

We attempted, by means of a similar model, to find the greatest number of links that could be joined by twisting pairs to form a simple closed chain. No motion was possible with six links, but whether or not seven was the limiting number remained uncertain, as the motions were very difficult to follow on account of the fragile nature of the model.

A mathematical demonstration one way or the other is much to be desired, for it would undoubtedly prove more than the mere fact of a limiting number; but I am of the opinion that for so general a proposition there must be, if any, a very simple proof. So I have been content to follow a line of thought suggested by the following facts, the more so as I have had time to do nothing else. But first let me state the problem in its most general form. To do that I must define constrained motion.

Generally speaking, a body is unconstrained when it can turn about any axis and translate in any direction. If it has less freedom than this it is constrained. But in pure mechanism we use the term to mean motion of the greatest possible degree of constraint, as when each point in one body can describe one line and only one line in relation to another body. The line traced may be straight, curved, or tortuous, in short, any line. A nut turning on a screw is a simple case of constrained motion where the paths are simple tortuous curves.

Now suppose a body, A, is paired to B in such a way that the relative motion is constrained. B is paired to C and C is paired to D and so on, and the last one of the series is paired to A, in each case so that the relative motion is constrained. Then if the relative motion of each body to every other body in the series is constrained, the number of bodies will be seven.

If this be true, it bears a curious analogy to another fact in kinematics; namely, that there are just seven different relations that can exist between two bodies as regards their relative motion;

1. Perfect freedom. 2. A point belonging to one is constrained to remain in a surface belonging to the other. 3. A point in one remains in a line in the other. 4. A point in one is fixed to the other. 5. A point is fixed as in the last case and another point is constrained to remain in a line. 6. Two points of one are fixed to the other. 7. Three points of one are fixed to the other.

In "Motion of Vortex Rings" by J. J. Thomson (p 93 et seq) it is demonstrated that, in a perfect fluid, if less than seven columnar vortices be arranged equidistantly around a cylinder, they will be in stable equilibrium as regards their relative positions, but that seven or more will be in unstable equilibrium Whether this seven has anything to do with the kinematic seven that we have been discussing, remains to be seen.

THE INTERNATIONAL ADOPTION OF PRACTICAL ELECTRICAL UNITS AND STANDARDS.

BY LOUIS B. HOWELL, '95.

During the latter part of August, one of the greatest assemblages of electricians the world has ever seen, met at Chicago. It was peculiarly fitting that such a congress,—an international convention,—should meet in the midst of an international gathering of people, and within the shadow of an international exposition, whose great success, whose very existence, was in a large measure dependent upon the power of electricity.

The proceedings of this congress embraced an unusual succession of interesting papers and discussions, whose importance can hardly be over-estimated; and pre-eminent among the results produced was the adoption of an international system of practical units. The Chamber of Delegates, a body consisting of a maximum number of five representative electricians from each of the leading nations of the world, was intrusted with the task of defining the value of the ohm, ampère, volt, coulomb, farad, joule, and watt, and of naming and defining the unit of induction. The work of previous congresses had been in the direction of securing a common system of units throughout the world, and although each had failed in attaining that result, it had rendered the time ripe for the action of the congress of 1893.

Of the work of the Chamber of Delegates, Professor Hospitalier

says in *L'Industrie Electrique:* "Their decisions deserve unreserved approval, for they do away with the last objections of those who were opposed to the international adoption of the system of units elaborated by previous congresses. It is certain that the system of practical units and standards, defined by the congress at Chicago, will be international, and that fact alone would justify the usefulness of the congress."

The proceedings of the Chamber were not open to the public, only a few privileged ones being admitted to its deliberations. Its report to the convention, as read by the secretary, Professor Nichols, was as follows:

"*Resolved*, That the several governments represented by the delegates of this International Congress of electricians be, and they hereby are, recommended to formally adopt as legal units of electrical measure, the following:

"As a unit of resistance, the international ohm, which is based upon the ohm equal to 10^9 units of resistance of the C. G. S. system of electro-magnetic units, and is represented sufficiently well by the resistance offered to an unvarying electric current by a column of mercury at the temperature of melting ice, 14.4521 grammes in mass, of a constant cross-sectional area and of a length of 106.3 centimeters.

"As a unit of current, the international ampère, which is $\frac{1}{10}$ of the unit of current of the C. G. S. system of electro-magnetic units, and which is represented sufficiently well for practical use by the unvarying current, which, when passed through a solution of nitrate of silver in water and in accordance with the accompanying specifications, deposits silver at the rate of .001118 grammes per second.

"As a unit of electro-motive force, the international volt, which is the electro-motive force that, steadily applied to a conductor whose resistance is one international ohm, will produce a current of one international ampère, and which is represented sufficiently well for practical use by $\frac{1000}{1434}$ of the electro-motive force between the poles or electrodes of the voltaic cell known as Clark's cell, at a temperature of 15° C. and prepared in the manner described in the accompanying specifications.

"As the unit of quantity, the international coulomb, which is the quantity of electricity transferred by a current of one international ampère in one second.

"As the unit of capacity, the international farad, which is the capacity of a conductor charged to a potential of one international volt by one international coulomb of electricity.

"As the unit of work, the joule, which equals 10^7 units of work in the C. G. S. system and which is represented sufficiently well for practical use by the energy expended in one second by an international ampère in an international ohm.

"As the unit of power, the international watt, which equals 10^7 units in the C. G. S. system and which is represented sufficiently well for practical use by the work done at the rate of one joule per second.

"As the unit of induction, the henry, which is the induction in the circuit when the electro-motive force induced in this circuit is one international volt, while the induced current varies at the rate of one international ampère per second."

The secretary also read the following report of the committee appointed by the Chamber of Delegates to consider the standard of light.

"They have had much discussion upon the various forms suggested for practical standards. and in particular upon the two specifications of lamps known as the amyl-acetate lamp of von Hefner-Alteneck and the pentane lamp of Vernon Harcourt. The only practical lamp actually presented to the committee, is the new von Hefner lamp, which, although it has been laboriously tested at the Reichsanstalt and reported accurate to within two per cent., has not received any extended trial in other lands. On the other hand, it was reported that the pentane lamp in its recent improved form, was preferred in England for the photometry of gas lights. There is the objection to the pentane lamp, that the composition of the commercial pentane is not sufficiently well defined ; and to the amyl-acetate lamp, that its color is too red in hue ; finally, the objection to all open flame lamps is that they are too liable to be influenced by the changes in the pressure, temperature, and moisture of the air. It is admitted on the other hand, that no electric lamp suitable for use as a convenient, practical standard has yet been realized. Under these circumstances there was a sharp division in the committee between those who advocated the von Hefner lamp as an independent standard, and those who desired to maintain a *statu quo* until further researches should have been made in various countries.

"It was proposed by Drs. Budde and Lummer, that the Hefner-Alteneck lamp constructed exactly according to the specifications of Mr. von Hefner-Alteneck, be introduced as a provisional, practical standard of light and that the problem of determining its value in terms of an absolute unit be left to subsequent investiga-

tion. On vote this was lost by two votes for, and four against. The following motion proposed by Messrs. Palaz and Thompson and amended by Drs. Budde and Lummer, was then carried unanimously.

"*Resolved*, That the committee, while recognizing the great progress realized in the standard lamp of von Hefner-Alteneck and the important researches made at Reichsanstalt, also recognize that other standards have been proposed and are now being tried, and that there are serious objections to every kind of standard in which an open flame is employed. It is, therefore, unable to recommend the adoption, at the present time, of either the von Hefner-Alteneck lamp or the pentane lamp, but recommends that all nations be invited to make researches in common on well defined practical standards, and on a convenient realization of an absolute unit."

Signed

J. VIOLLE,	E. BUDDE,	SYLVANUS P. THOMPSON,
A. PALAZ,	O. LUMMER,	EDW. L. NICHOLS.

With the exception of the "henry," all of the units described above had been in common use for some time, and simply lacked the sanction of their users in congress assembled. As a unit of induction, the "henry" was originally proposed by the American Institute of Electrical Engineers, as being in accordance with the well-established precedent of honoring those who have been pre-eminent in the history of electrical science, and as conferring that honor upon a man who has done much to advance our knowledge of electricity in general and of induction in particular. At the congress of Frankfort held in 1891, the American delegates were instructed to introduce the "henry" as America's choice for the name of the unit of induction, but they, finding the sentiment toward it not favorable, thought it better to drop the matter until the Chicago congress. The Germans were its chief opponents; France and England, although using the names "quadrant" and "secohm" to a great extent, were favorable to "henry." At Chicago there was no dissension; Mascart of France introduced the name, Ayrton of England being his second, and it was adopted unanimously, thus paying a graceful tribute to American genius, so well exemplified by the great exposition near at hand.

The second portion of the work of the Chamber of Delegates, was the adoption of a standard and unit of light, but after long deliberation they decided that the perfect lamp is yet to be produced. Its essential qualification is, that anyone reading the definition and specifications, should be able to make such a lamp

and produce from it a standard quantity of light; that is, whatever direction the attempt to obtain a standard source of light may take, whether it be an incandescent solid, or an open flame, it must be capable of ready reproduction.

The matter was left by the congress in the state indicated in the report of the committee, but with characteristic energy the American Institute of Electrical Engineers has taken the question in hand, and determined that the solution of this all-important question shall be obtained in this country. To this end, it has appointed a committee, the chairmanship of which has been offered to Professor Nichols, and probably will be accepted by him. The most important investigations of this committee are therefore likely to be made here at Cornell, thus furnishing subject for investigations, which probably will involve several years' study on the part of the Physical department, and other advanced students in electricity.

May the honor of bringing this problem to a successful solution belong to Cornell!

THE FLOW OF WATER THROUGH AN ORIFICE.*

BY S. H. BARRACLOUGH.

The experiments described in the following paper were undertaken for the purpose of determining the law which governs the flow of water through an orifice in the end of a tube of uniform section.

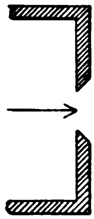
The orifices were cut in the faces of ordinary pipe caps with a sharp edge on the side toward the current as shown in the sketch (fig. 1). Before cutting the orifices the caps were put in a lathe and carefully faced on the inside. Six caps were thus prepared with orifices of 3/8", 1/2", 5/8", 3/4", 7/8", and 1" diameter respectively.

The caps themselves were 2" in diameter or, more correctly speaking, screwed onto a pipe of 2" internal diameter in the manner shown in the accompanying sketch (fig 2). This figure shows also the general arrangement of the apparatus.

A is a valve through which the water had to pass before reaching the orifice and by means of which the pressure could be varied as required for the different tests.

* These experiments were made by Mr. J. Lange, M.E., and the writer in connection with the class on consulting engineering.

Fig 1.



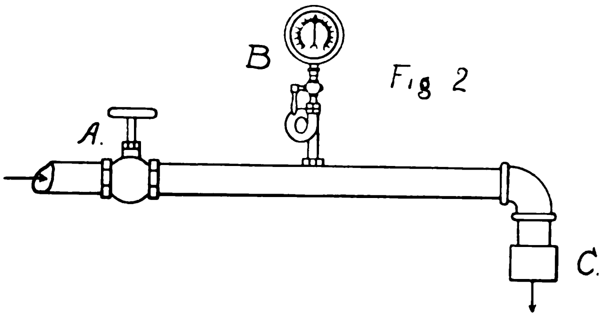
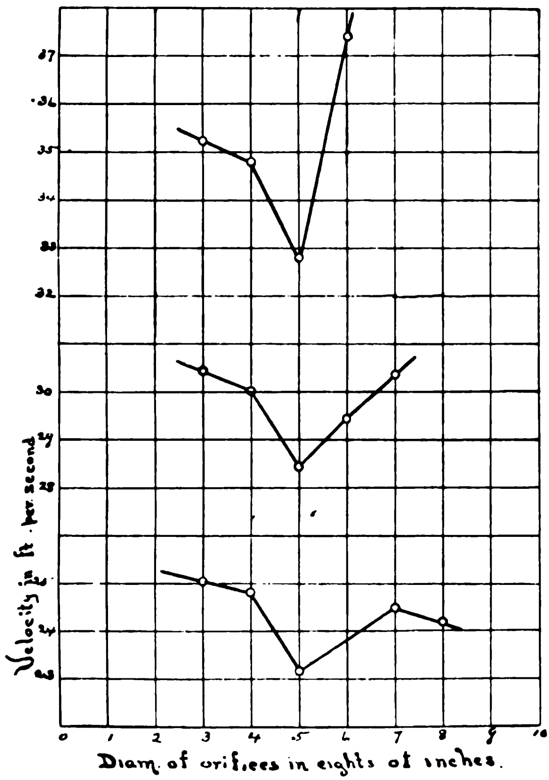


Fig 2



B is a steam gauge by means of which the running pressure in the pipe was observed. This gauge was calibrated by comparison with the mercury column before beginning the tests.

C is the cap, through the orifice in which, the flow is to be measured.

The distance from the gauge to the orifice was 5 feet. The

error made in reading the gauge did not probably amount to more than ¼ lb., so that the heads as given may be taken to be correct within six inches. These heads have been corrected for the difference in height between the centre of the gauge and the orifice.

To determine the rate of flow, the water passing through the orifice was received in a rectangular tank, each inch in the depth of which corresponded to a volume of one cubic foot. The time required for the level of the water to rise by 12 inches was observed, and from this the flow per second was calculated. At least two observations of each time interval were taken, and it was found that the mean of these in no case differed by as much as a half of one per cent. from the extremes.

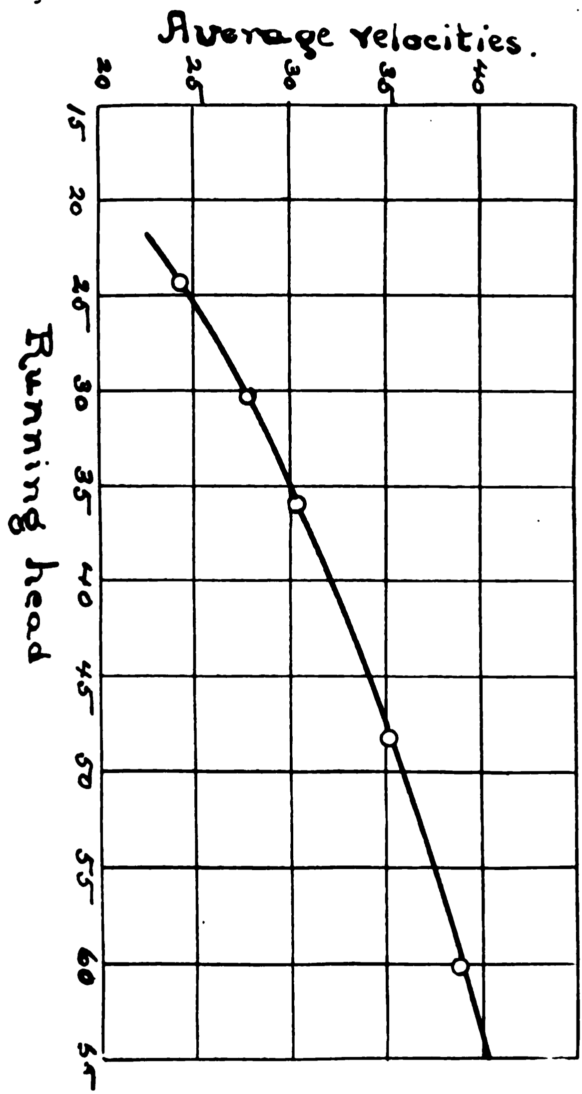
The means of the observations and the calculations therefrom are given in the accompanying log.

Diameter of Orifice.	Heads.				
	24.2	30.1	36.0	48.0	60.3
	Seconds Required for 12 cu. ft.				
⅜ . . .	624.9	. . . .	514.0	444.0	399.4
½ . .	354.8	. . . .	291.2	252.4	227.4
⅝ . . .	243.2	. . . .	198.0	171.6	. . . .
¾ . . .	164.1	. . . .	133.0	104.8	. . . .
⅞ . . .	117.2	103.1	94.7	. . . .	. . . .
1 . . .	91.0	. . . .	. . . .	. . . .	. . . .
	Cubic Feet per Second.				
⅜ . . .	.0192	. . . .	.0234	.0270	.0300
½ . . .	.0338	. . . .	.0412	.0476	.0513
⅝ . . .	.0494	. . . .	.0606	.0701	. . . .
¾ . . .	.0732	. . . .	.0903	.1144	. . . .
⅞ . . .	.1024	.1164	.1268	. . . .	. . . .
1 . . .	.1320	. . . .	. . . .	. . . .	. . . .
	Velocities through Orifices in Ft. per Sec.				
⅜ . . .	25.03	. . . .	30.44	35.23	39.17
½ . . .	24.80	. . . .	30.22	34.80	38.70
⅝ . . .	23.18	. . . .	28.44	32.82	. . . .
¾ . . .	23.85	. . . .	29.45	37.40	. . . .
⅞ . . .	24.50	27.81	30.35	. . . .	. . . .
1 . . .	24.18	. . . .	. . . .	. . . .	. . . .

The discussion of the observations may be divided into two parts:

(a) That treating of the variation of flow under the same head through different sized orifices.

(b) That treating of the variation of flow under different heads through any one orifice.



(a) It might, at first sight, be thought that the velocities through orifices of different diameters under a constant head

would themselves be constant, and the observations as taken do not conclusively prove that this is not the case, but they certainly seem to indicate the presence of a minimum velocity somewhere in the neighborhood of the velocity through an orifice of ⅝ diameter under any one head. The diagram on page 77 shows the velocities per second through the various orifices, coördinated with the diameters of the respective orifices in eighths of an inch. No attempt has been made to smooth the curves in any way; they are merely drawn to illustrate the probable existence of a minimum velocity and as the present set of observations is not sufficiently numerous to definitely prove the fact it will not be further treated of here.

(b) As a consequence of the foregoing, the second part of the discussion of observations will now be on the variation of the average flow through all the orifices under different heads. The observed running heads and the corresponding average velocities are given in the following table and are coördinated as shown in the accompanying diagram.

Running head	24.2	30.1	36.0	48.0	60.3
Average velocities . . .	24.3	27.8	30.0	35.1	38.9

If it is desired to use an orifice in the end of a pipe as a water meter one of two courses may be pursued. In the first case the velocity corresponding to any observed running head may be read from a curve similar to the one just shown and the flow per second can then be deduced therefrom; or, secondly, from a set of observations similar to the foregoing, the coefficients of velocity and contraction of area for orifices of this class in general may be deduced as shown below, and the flow per second calculated from these coefficients and the observed head.

The coefficient of contraction was deduced in the following way:

Let $H =$ the total actual head producing overflow,

then $H = h_v + h_r$.

Where $h_v =$ the head producing the actual velocity,

$h_r =$ the head due to pressure in the pipe.

$$\text{Theoretically } v = \sqrt{2gH}$$

$$\begin{aligned} \text{actually } v &= C\sqrt{2gH} \\ &= C_vC_c\sqrt{2gH} \\ &= C_vC_c\sqrt{2g(h_v + h_r)} \end{aligned}$$

Where $C_v =$ a coefficient of velocity,

$C_c =$ a coefficient of contraction.

h_v is the head which produces the velocities given in the log. Calling these v we have $h_v = \frac{v_2}{2g}$.

$$\therefore\ v = C_v C_c \sqrt{2gh_r + v^2}$$

$$\text{or } v^2 = C_v^2 C_c^2 (2gh_r + v^2)$$

$$C_c^2 = \frac{v^2}{C_v^2 (2gh_r + v^2)}$$

$$= \frac{1}{\frac{C_v^2\, 2gh_r}{v^2} + 1}$$

h_r is the running head which we actually observe, C_v may be assumed as .96 and v is a known quantity, so that in the above expression for C_c all the quantities are known and the values of C_c for the different heads may be readily deduced by substituting for C_v and g, thus:

$$C_c^2 = \frac{1}{(.96)^2\, 64.4 \frac{h_r}{v^2} + 1}$$

$$= \frac{1}{59.35 \frac{h_r}{v^2} + 1}$$

and for h_r and v^2 as shown in the following table:

v	h_r	$\frac{h_r}{v^2}$	$59\ 35 \frac{h_r}{v^2} + 1$	$\frac{1}{59.35 \frac{h_r}{v^2} + 1}$	C_c
24.3	24.2	.04095	3.435	.2915	.540
27.8	30.1	.03895	3.315	.3017	.549
30.5	36.0	.03873	3.300	.3032	.550
35.1	48.0	.03895	3.315	.3017	.549
38.9	60 3	.03990	3.370	.2970	. 545

The mean value of C_c is .547, but the third figure is unreliable so that the coefficient of contraction will be taken as .55. It has already been assumed that the coefficient of velocity is .96 and therefore the total coefficient of efflux becomes

$$55 \times .96 = .53.$$

It should be noticed that this coefficient is for efflux under the exact conditions described; *viz.* with the pressure gauge some 5 feet from the orifice and with an elbow on the pipe between the orifice and the gauge.

Any change in these conditions would alter the running pressure and so affect the value of the coefficient.

With this understanding, however, the general conclusion may be stated that the flow per second through an orifice of this class is

$$Q = CF\sqrt{2gH}$$

Where $C = .53$.
$F =$ the area of the orifice.
$g =$ the acceleration of gravity.
$H =$ the total head acting to produce flow.

BOOK REVIEW.

Compound Locomotives. By A. T. Woods, (M. M. E., Cornell, etc.,) revised and enlarged by D. L. Barnes, A.M., C.E.. Chicago, Railway Age, Publisher. 1893. 8 vo., pp. 330. $2.

This excellent treatise upon the Compound Locomotive was originally prepared by the late Professor Woods, in 1889, and issued in the form of a little 12 mo. book, containing a general and illustrated description of the various forms of compound locomotive which had come into more or less extensive use in this country and in Europe. It was an admirable piece of work, and was well received by engineers in all departments. The present work is very much more extensive, and is more complete in the sense that the original descriptive work has been largely supplemented by the introduction of chapters of importance treating of the theory and proportions of the machine, and giving most valuable practical information in regard to the methods of reading, interpreting, combining, and computing the indicator diagram of the compound engine; the conditions of economy and of satisfactory handling of the engine; the points of similarity and difference in design, construction and operation, in the comparison of the simple with the compound engine, and many details of great importance and interest. The principal new types of locomotives are illustrated, and such as have been brought into successful use since the date of the first edition have been here described fully and with reference to good working drawings. The names of the authors give guarantee that all this work is well-done.

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THE SIBLEY JOURNAL board has decided to extend the time during which the members of the Junior class may compete, to December 5. It is imperative, however, that all matter be submitted not later than that date.

THE PRESIDENT'S ANNUAL REPORT TO THE TRUSTEES.

The President's annual report to the Board of Trustees was presented to that body, at its last meeting, October 6th, and has been printed for the use of Trustees and Faculty. We are permitted to abstract from it the most important and interesting points, for Sibley College students and alumni, with an occasional

comment or additional fact, usually originally obtained from the reports of the Director of Sibley College; a portion of which latter report has been published, by permission, by the *Scientific American* Supplement.

The report of President Schurman is concise, to the point, and maintains throughout one leading theme:—the opportunity offered at Cornell University for the investment of large amounts of capital in the promotion of higher education. The opportunities at Cornell are exceptionally great—much greater than in most other such institutions, in consequence of the fact that it covers a broader ground and a greater variety of work, and, on the whole, works upon a higher plane than, perhaps, any other university at home or abroad. Its provisions for a "liberal and practical" education of the people are so extensive and complete that nowhere else, probably, can be found equal opportunities for the investor in this kind of business; and it would probably also be impossible to find, anywhere else, such assurance of ample return upon such investments.

The report shows a growth, from 1884–5 to 1892–3, of 200 per cent., of from 575 up to 1700 students registered, with increase of the instructing force from 61 to 142, or of about 150 per cent. In other words, somewhat larger numbers are taught per teacher than formerly; but the proportion—twelve to one—is not too large. Two-thirds of the teaching force was, at the earlier date, composed of full professors; to-day about one-half are instructors and assistants. But instruction is considered to be even more efficient than formerly; partly in consequence of a better distribution of work and largely because of the remarkably high quality of the body of instructors; members of which are continually passing into professor's chairs here and elsewhere. New professorships and an enlarged faculty, in view of the uninterrupted growth of the University, are still demanded, and, among them, not only professorships of languages, sciences and literatures, but also in railway machinery construction, mining engineering, and chemical engineering.

The total enrollment of 1892–3 was 1918, of whom 1700 were in the University, and the balance in the summer school, and in a "short course" in agriculture. A table shows the rise in numbers from 1868–9 to 1892–3 to have been from 412 to 1700, of whom one-fourth were in the technical courses at the earlier, and one-half, nearly, at the later, date. The absolute gains are 1300 total, 600 in the academic, as against 688 in the technical, courses or

200 per cent., as against 700 per cent. Since the Law School was established, it has gained a total of 176; the technical courses have gained, in the same period, 326 or twice as many; the University, as a whole, gaining 700 The technical schools gained, last year, 54, the law school 53, the University, 63; the gain of the latter being substantially all in Sibley College; which gained also an uncredited body of graduate students, amounting, according to the Dean's report, to about 20; the total number studying for M.M.E., in 1892-3, being 31.

Several pages of the report are devoted to the condition and needs of the largest division of the University—Sibley College—and even this is insufficient for the presentation of its case with justice to either the college or its individual departments. Attention is called to the rapid and continuous elevation of the requirements for admission which has distinguished this college during the eight years of its existence in its present form, and the fact that they are now high as compared with the majority of other institutions of the kind. This increase in preparation has come to be necessary, since the engineer is now "a member of a profession and his training is to-day higher than that generally received by the members of those professions which formerly monopolized the designation of learned." It is suggested that still further preparatory work may yet be demanded, "raising" the total to that demanded for entrance into the courses in arts and philosophy. We presume, however, that, as the requirements for admission to a professional course are simply those demanded for successful entrance upon professional work, this consideration, and not a comparison with other and literary courses, must determine the nature and extent of the preparation asked by the college. It may prove to be greater, it is very likely to be less, than the apparent requirements of those courses. The fact is that to-day, although apparently less, the student brings with him to the University the same length of preparatory work, coming as he does at the same age as his comrade entering the literary departments, and is, in fact, as well educated in his way as is the latter in his. Practically, the students entering the technical departments bring with them equal preparation with others and, for their purposes, a better one.

The President makes an appreciative reference to the generous act of Mr. Hiram W. Sibley in building for Sibley College a large and commodious new structure, following his father's plans in detail, and describes its arrangement of rooms and disposition of

space. "Those acquainted with the present overcrowded condition of the class-rooms, laboratories, and shops, in Sibley College, will know what great relief Mr. Sibley's gift brings to the University." This building is proving one of the most satisfactory and best-constructed buildings on the campus, and in materials and workmanship, as well as in its plan and interior arrangements, is most thoroughly commendable. It is a credit to its architect, Professor Osborne, who sketched all the plans originally approved by the Founder.

The finances of the University as related to Sibley College are published as a text for the plea that, even here, where students pay highest tuition fees, and turn into the University so exceptionally large a sum, there is a deficit, as here figured, of $35,000. "The showing in other departments would be still worse;" though this showing is probably, fairly judged, an extraordinarily favorable one. The deficit for the whole University, on the same basis – comparing costs with returns from students—and allowing $100,000 annually as an average outgo on building and repairs, is $400,000, less tuition fees, or a net $300,000, about $200 per student; and this is over *three times* the amount figured against Sibley College; which contains one third the student-body of the University, pays one-half the fees, and is probably the most economically operated and least costly school, of a high character, in this department, in the world. Its students pay a special tax covering all extra costs of the professional work in shop and laboratory, and the balance of their instruction, costing, on the whole less than the average, being given to large classes, and largely by the hardest-worked and lowest-paid teachers, is paid for by them at the highest rates charged in the University.

Otherwise stated: the deficit of the University, instead of being $300,000 per annum, as here estimated, would become, if all departments were as productive, pecuniarily, as Sibley College, but about $200,000, and about twice as many students could be carried on the present endowment as now, with equal efficiency of instruction; or, again, accepting the alternative, doubling the efficiency of instruction, with an equal number of students, would give Cornell a standing such as no college in this country has yet attained, or is likely to attain in this generation. Probably no existing technical school is to-day doing its work at once with equal efficiency and equal economy with Sibley College; yet its students are compelled to pay fifty per cent. more than the average student in the University, while twenty-five per cent. less, per capita, is expended on their account. The students for whom

the University was mainly inaugurated are those of whom most is exacted and for whom least is expended.

The report speaks of the finances of Sibley College as exhibiting an "unfavorable balance," though "the showing would in most other departments be still worse;" but it is probably actually the most favorable showing ever made, considering the extent and quality of the work. Had there been no such deficit as is here figured, the President's conclusion that it "constitutes a strong plea to the wealthy friends of the University of practical education" would lose its whole strength. Were the students of Sibley College to pay the *whole* costs of instruction, say $200 per annum, there would be nothing left for its friends to do, and the endowment of the University would find absolutely no application in the promotion of that work which it was so largely intended to carry on, and would not at all benefit the students for whose advantage it was principally given. Endowments are needed to relieve students and their parents from just such burdens as are now carried by Sibley College students in such excess over all others. Such aid is the more essential, in this line of higher education, since, as the President remarks: "Experience and imaginative foresight alike indicate the direct utility and the great value of instruction in mechanical engineering for establishing on firm foundations the material basis of American civilization."

The student feels that in an institution organized mainly for the promotion of this very work, this is a state of affairs hardly satisfactory to students, to the people who founded it, or to those who desire consicienciously and precisely to carry out the intent of the generous men who did so much to second the work of the National Legislature. But, as the President intimates, the only difficulty in the way of fully satisfying all demands, legal, philanthropic, or other, is that of finance. He estimates that additions to the endowment to the amount of $3,000,000 are needed to do the work now imperatively demanded. Among others in Sibley College, are needed "a new professorship of engineering design, one of mechanical engineering of railways"—locomotive engineering—"and a great laboratory for engineering research."

THE OPENING YEAR.

The new college year opens full of promise, despite the "hard times," which, undoubtedly, are seriously menacing every department of business. The number of students in the University

is considerably greater than last year at the corresponding dates, having attained the figure 1700, or more, which was only reached in 1892–3 at the close of the year. Sibley College shares, as usual, in this prosperity; its list numbering about six hundred. The entering classes are said to be better prepared each year and, this year, to exhibit spirit, talent, and maturity, in a most satisfactory degree; and they are reported to show rare capacity in their work in all departments. This great body of students is quiet, gentlemanly, earnest, and industrious, and impresses strangers, particularly, with a scholarly and courteous manner and bearing.

The work of the term begins in a very satisfactory manner, in all departments. Lectures and class-room work began promptly and smoothly and some interesting improvements and additions to the schedule will probaby find place in the course of the year. The improvements proposed are especially important in the Department of Drawing, in which several new lines of specialized work are in preparation. The plans of the Director, at the very first, contemplated a correlation of the work of the lecture room with that in the drawing room, in such manner that the one should illustrate, and furnish the theoretical preliminary for, the other. This has been kept constantly in view, and the result has been most satisfactory. It has compelled the preparation of a new systematic and extensive course of exercises and studies, especially for junior work, and this has involved continuous work on the part of the instructing force in its preparation, its perfection, and its steady improvement with the equally continual progress of the course. No one unfamiliar with the subject can appreciate the number, the character and the complexity, in some cases, of the drawings which have been required to furnish regular graded exercises and a gradually specialized course of instruction in the arts of designing and drawing, such as is required by the large and growing classes of Sibley College. And this work is just now, in view of the contemplated improvements of these courses in the drawing room, greater than ever before. The whole sophomore course is to be brought into shape, as a completely new course; the junior course is to be given a more extended and perfect form than ever; and the graduates and seniors are to have a number of options in special lines of work; where they are prepared to take them. The preparation of these extensive courses is assigned to the several members of the instructing force and their office and outside work is, at the moment, as ex-

tensive, very nearly, and as important—possibly more important, in some sense—as their work with their classes.

Professor Williams is completing the work on the junior course, and is given some extra time for the work by assistance from Mr. Malvern, who relieves him of some of his afternoon work with the classes. It is hoped to have some of this new work ready for the winter and spring terms. Meantime, also, Mr. J. S. Reid is giving all available time to the preparation of courses of work in locomotive and railway machinery construction for specialists, which presumably will be taken mainly by graduates and advanced seniors. Mr. David Reid is similarly engaged in the working up of the air and gas engines, for the same classes of students. When all this work is completed, it is hoped that the courses in this department will prove to be of unexampled value. No such courses of instruction have yet been published, and they will probably prove unique ; as few, if any, technical schools or colleges have been able to offer such advanced courses as are now coming to be taught in Sibley College. It has been hoped and expected that Professor Williams would be able to publish his special work in book-form soon ; but he has been compelled to defer this scheme ; his time being too much occupied by the class-room and office work of the department to permit him to do much work of late, in this direction.

In the lecture-room courses, the advanced work of Professors Ryan and Barr in mechanical and electrical engineering, and of Professor Durand in marine engineering, is steadily growing in extent and value, and furnishes the scientific foundation of that of the designer in the drawing room. A large amount of practical data, with plans and specifications, obtained by constant communication with the members of the profession engaged in the greatest work of the time, supplies the material for study and criticism, and gives opportunity to check the work of the student by comparison with that of the experienced designer and constructor. This material is collected, in part, by sending out blanks suitably arranged with tables, into which the desired data may be introduced ; thus securing systematic arrangement of these data, and insuring the supply of all that are needed for the purpose in view.

In the shops, the work is steadily gaining in value and excellence, and new designs and new constructions are becoming constantly more common. Some work of considerable magnitude and importance as steam engines, pumps, dynamos, and other

machinery of hardly less interest and importance, is always on the floor, and the students not only acquire skill rapidly, by the systematic methods of instruction and the practice of the graded exercises of the early part of the course, but learn also something of the ways of handling large work and of management of shops doing this class of work.

The new building, given this year by Mr. Hiram W. Sibley, is progressing rapidly and well, and will be ready for occupation, it is expected, in the Spring term. The Easter vacation is likely to see all the material transferred from the old to the new construction, the museums re-established, and class-rooms and drawing-rooms reduced to order and comfortably arranged, for the first time in several years ; the space allowed being now very fairly ample for the number of students under instruction ; although the estimates of the Director, at the inauguration of the organization, would have allowed but about four hundred students to space now provided for six hundred.

THE SIBLEY JOURNAL is indebted to *Power* for the cuts used in illustrating Professor Carpenter's article on Steam Consumption from the Indicator Diagram, which we publish in this issue.

CRANK SHAFTS.

—If all the telegraph lines of the world were combined and stretched in one straight line, they would reach 881,000 miles, or enough to encircle the earth thirty-three times.

—The new Niagara Power plant to be installed by the Westinghouse Electric and Manufacturing Company will consist of three two-phase generators of 5000 H. P. each, giving an electromotive-force of 2000 volts.

—A remarkable case is cited of a piston rod, which has been in steady use for nearly nine years, averaging 285 days in the year, each day being of eight hours. In that time it has traveled a total distance of 35,795 miles within its short range of motion in the cylinder.

—In his recent report made to the Palestine Exploration Fund, Mr. F. J. Bliss mentioned a blast furnace discovered at Tel-el-Hesy, the sight of ancient Lachish, so constructed as to heat currents of air before they reached the tuyeres. Thus these researches seem to show that the hot air blast is at least 3300 years

old and not so modern an improvement as we have been accustomed to think.

—There are now being sent out from Sibley College to the prominent manufacturers of machinery throughout the United States letters asking for data that will be of help in forming a library of information useful to our department of Machine Designs. In many cases the various manufacturing concerns have their own rules and formulae for designing the different parts of machinery, which, in some cases are kept secret, but which, in others, the designers are willing to make known. The purpose of Sibley College is to collect and tabulate all obtainable data that will be of use to its department of Machine Design.

—A method for producing solid steel ingot castings by centrifugal force has been successfully used in Sweden for two years. The ingot molds are placed on a platform and filled in the usual manner, after which the platform is revolved at the rate of 125 revolutions per minute. The molds immediately take a horizontal position, due to centrifugal force, and a pressure is induced in each one equal to 38 times the weight of the metal. The diameter of the platform is about 67 feet, giving a linear velocity of 10000 feet per minute to the molds and inducing a pressure of 500 to 600 pounds per square inch on the metal. A loss of 40% by defective ends is avoided, and very solid castings produced.

—The U. S. Consul at Rotterdam, Mr. W. E. Gardner, reports to the State Department that the Dutch training schools for young engineers are proving very successful and useful. He says that "next to the educators themselves, the employers of skilled labor are the most prononnced advocates of trade-schools, which do not cheapen, as these men testify, but only improve the grade, of skilled labor ; making it not only more profitable to the employer, but more remarkable. The old adage that 'there is always room at the top' is proved anew in the experience of this country, thus far, with its trade-school graduates."

—Professor James Bryce, a member of Parliament in England (we do not employ professors in this manner here) in a recent address before the institute of Civil Engineers, London, pointed out that in imaginative fiction no one has ever chosen an engineer to be the villian of a romance. This is certainly true and means a great deal. Priests are sometimes pilloried in this manner, but engineers never. This is not an accident altogether : there is a cause for it. An engineer deals with truths as nearly as human intellect can determine thereon. His works are proved by computation and his work rests on the immutable laws of mathe-

matics and observed results. Villiany is untruth, sometimes the result of faith or credulity. It is always hypocritical because deceit is the foundation of it. This may be but one out of many causes; but the fact remains that there is no direct affinity between villiany and applied science. Results find more promising business than technical work. *Industry;* July 1893.

PERSONALS.

'88.

G. W. Bissell, a former instructor in the mechanical laboratory of Sibley college is in charge of the department of Mechanical Engineering of the State Agricultural College at Ames, Iowa.

'90.

W. N. Smith holds an excellent position with the Chicago City Railway Co. He is acting as assistant engineer on the company's newly installed electric lines on the South Side.

'91.

W. H. Meeker occupies the Chair of Assistant Professor of Mechanical Engineering at the Iowa State Agricultural College.

R. T. Burwell has a position at the New Orleans Sugar Experiment Station in New Orleans, Louisiana.

'92.

Carl F. Kress is in the employ of the Cambria Iron Works, Johnstown Pa.

Stuart G. Barnes is with the Eager and Averill Co. Dynamo Mgrs. Syracuse, N. Y.

F. B. Corey is with the Elektron Mfg. Co. Boston Mass. He has charge of their extensive electric crane department.

H. N. Wood on account of his excellent work in the recent examinations has his name on the list of those eligible for the position of Assistant Engineer in the Revenue Marine.

'93.

E. P. Chapin is with the Walton Switch Co. at Jenkintown Pa.

H. G. Geer has an Instructorship at Johns Hopkins University Baltimore Md.

J. H. Van Buskirk has a position in the New York Central Shops at Lancaster N. Y.

R. S. Hale is in the General Manager's Office of the Edison Electrical Illuminating Co. Boston Mass.

F. J. Stewart holds the position of draughtsman with the Westinghouse Electric Co. of Pittsburgh Pa.

A Manual of the Steam-Engine.

BY

ROBERT H. THURSTON, A.M., LL.D., DR. ENG'G;

Director of Sibley College, Cornell University; Formerly of the U. S. N. Engineers; Past President Am. Society Mech. Engrs.; Author of "A History of the Steam-Engine," "Manual of Steam-Boilers," "Materials of Engineering," Etc., Etc., Etc.

Part I. STRUCTURE AND THEORY.—History of the Steam-Engine. Structure of Modern Engines. Philosophy of the Steam-Engine. Thermo-dynamics of Gases and Vapors. Theory of the Steam-Engine. Compounding; Jacketing; Superheating. Efficiencies of the Steam-Engine.

Part II. DESIGN, CONSTRUCTION, OPERATION. Design of the Steam-Engine. Valves and Valve Motions. Regulation; Governors; Fly Wheels; Inertia Effects. Construction and Erection. Operation; Care and Management. Engine and Boiler Trials. Specifications and Contracts. Finance; Costs and Estimates.

Each part 8vo. 900 pages, $7.50; or two parts at once, $12.00.

Published by J. Wiley & Sons, 53 E. 10th St., New York City.

Those who desire an edition in French, can obtain it of Baudry et Cie, Rue des Saints-Pères 15, Paris.

A MANUAL OF THE STEAM ENGINE is here presented to the student and practitioner in steam engineering, for the first time, as is believed, which is a complete treatise upon the steam-engine of the present day, from both theoretical and practical stand-points. Earlier treatises have usually either given simply the thermo-dynamic theory of the engine, the pure theory of an ideal, non-existent, machine, or working drawings, mainly, without complete scientific discussion. In this work we have a complete, though condensed, and systematic account of the rise and progress, and of the present forms, of the standard types of engine; a summary of the scientific principles finding application in its design and construction; an outline of the growth of the science of thermo-dynamics and of the general physical, as well as the merely thermo-dynamic, theory of heat-engines; the theory of the real, as distinguished from the ideal engine; accounts of the various methods of promoting their economic value,

and an outline of the theory of their efficiencies. In the second of these volumes, are considered the design, the construction, and the operation of the engine ; its care and management when off duty ; methods of determining the efficiency and economy of the engine and boiler ; forms of contract ; and specifications insuring correct design and good construction. A chapter on the finance of the engine and its operation concludes this part.

Very much of this work is entirely new. The history of the engine is brought up to date and is treated in a philosophical manner ; the same is true of the account given by this author of existing constructions, including the "high-speed" and the "multiple cylinder" engines. The historical account of the development of the modern and complete theory of the real, as well as of the ideal, engine is introduced for the first time into a treatise on the modern steam-engine and thus brings the subject up to date : showing clearly how engineers and men of science have come to see precisely what are the exact forms of the wastes of energy in the steam-engine and other motors deriving their power from heat energy. It exhibits as clearly the directions in which further improvement is to be sought, and the secrets of the high efficiency of the best modern engines. The thermo-dynamics of working substances in heat-engines is thought to have been here rendered exceptionally clear by the combination of the methods of treatment of the Continental with those of British writers on this subject ; while the distinction between the purely thermo-dynamic, and the actual case, in which thermal, as distinguished from thermo-dynamic, action is observed, is carefully brought out. The theory given is that of the "real engine," as actually constructed and operated, and as affected by not only thermo-dynamic but all other wastes. The best work of all earlier writers is here made available to the reader.

On the whole : the publishers are convinced that purchasers of this work will find it full of new and valuable matter, combining all the information that should constitute such a treatise as this is, by its title, indicated to be. The long and varied experience of its author, including many years of practical experience in the design and construction, and in the actual management of steam machinery, as well as his equally extended experience as a teacher of the theory of engineering, and his great opportunities for research, and in all forms of practical investigation, should be ample assurance that the work will have peculiar value to theorist and practitioner alike. The fact that it has already been found useful in the offices of the leading engineers of the time, at home and its translation abroad, and in the highest classes of

technical schools giving graduate instruction in engineering, may be taken as fully confirming our estimate of its probable successful occupation of the position of a standard treatise on the theory and the practice of steam engineering. The appended extracts from reviews by leading periodicals generally accepted as authoritative, will show how promptly and completely the MANUAL has been accepted and welcomed by members of the profession in Great Britain and on the continent of Europe as well as in the United States.

REVIEWS.

We know of no other work on the steam-engine which fills the field which this work attempts, and it therefore will prove a valuable addition to any steam engineer's library. It differs from other treatises by giving, in addition to the thermo-dynamic treatment of the ideal steam-engine, with which the existing treatises are filled *ad nauseam*, a similar treatise of the *real* engine.—*Engineering and Mining Journal, New York City.*

The author's experience during twenty-five years of unintermitted employment as a specialist in technical college work, and of thirty years of practical experience and work in the design, the construction, the management, and the scientific investigation of the principles of the steam-engine, and his careful observation of its gradual development, qualify him peculiarly well for the undertaking and successful completion of a work of this kind, which will undoubtedly be considered a standard work by the professional engineer and student.—*American Machinist, New York City.*

The author is so well known as one of the highest and most reliable authorities upon the steam-engine that one unconsciously looks for the best from his pen, and we are not disappointed. The book is in the style familiar to readers of other works by this author, is clear at all times and concise, yet not at the sacrifice of understanding.—*Journal of Commerce, Boston.*

This work is an epitome of the steam-engine in every sense, and we unqualifiedly recommend it to our readers engaged in the practical handling or management of steam ; to all such we would say "get it" as a standard volume of educational excellence.—*Marine Record, Cleveland.*

The present volume is in no wise inferior to the author's previous works, and is in many respects superior; or rather it is a complement to the work he has hitherto done in the same direction ; a boiling down, as it were, of the wide knowledge gained by years of observation and practical experience in the shop and class-room. Starting with an exhaustive history of the steam-engine, Professor Thurston proceeds to show it as it is built to-day, and then to give the theoretical reason why it is so built.—*Weekly Stationary Engineer, Chicago.*

The first part of this work we noticed some time ago. Any work from the pen of Professor Thurston must be treasured, and although this volume is intended as a text-book for very advanced students, it must prove invaluable to the practicing engineer. The work must be seen and studied to be appreciated. We can but say that the subject has been handled ably and exhaustively, and by as competent a man as there is in the country to speak on the subject of which he treats. The book is beautifully printed and illustrated.—*American Manufacturer and Iron World, Pittsburg.*

Professor Thurston is a recognized authority on this subject all over the world, and no one is better fitted for writing a manual of the steam-engine than he is. He has written several important technical books before, but nothing equal to this one. It is a standard work of study and reference, and will be in the library of every mechanical engineer in the country.—*Scientific and Mining Press, San Francisco.*

All that is necessary to say of this second volume of Professor Thurston's great work is that it upholds fully the promises of the first volume. Design, regulation of speed, construction and erection, operation, care and management, engine and boiler trials, specifications and contracts, and finance of steam engineering are the topics more particularly covered. Its size, style and author are enough to make it a *sine qua non* for every engineer who wishes to keep abreast of the present day.—*Scientific American, New York City.*

No such thorough treatise on the steam-engine has ever before been issued. —*Marine Journal, New York City.*

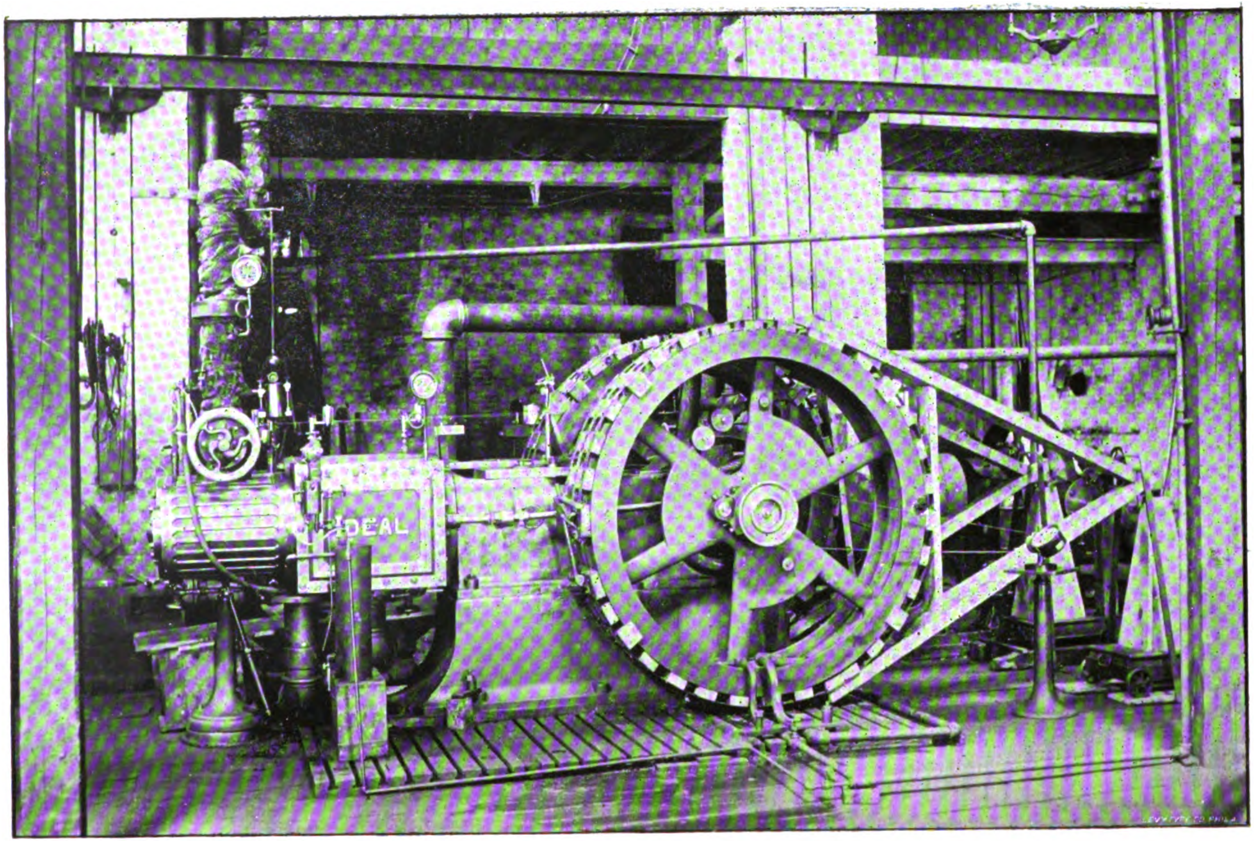
While Professor Thurston, on the title page, states that the work is intended for engineers and technical schools, it can be read with profit by any one interested in steam engines, as the mathematical parts are not at all essential to a fairly complete mastery of its contents, although there are some portions, as for instance those relating to inertia effects, which are rather beyond the comprehension of one not well versed in mathematics.—*Journal Franklin Institute, Philadelphia.*

In this the most recent important treatise on the steam engine, Professor Thurston has produced a work which deserves to long occupy a foremost place in this branch of engineering literature. The author has from time to time published contributions upon various subjects connected with the steam-engine, which have invariably been distinguished by originality of treatment and perspicuity. The work is written in the Professor's usually pleasant and interesting style, and fully sustains his reputation as an author. A word of praise is due to the publishers, who have produced the work in their customary high class manner.—*Mechanical World, Manchester, England.*

The hope with which we concluded the notice of the first volume of this work has been realized, and our expectations in regard to the importance of the second have not been disappointed. The practical aim has been fully carried out, and we find in the book all that it is necessary to know about the designing, construction and operation of engines; about the choice of the model, the materials and the lubricants; about engine and boiler trials; about contracts. The volume, which closes with an original and important study of the financial problem involved in the construction of steam-engines, is necessary to constructors, useful to students, and constitutes a collection of matter independent of the first part, in which the theory is developed. *The publication is a success worthy of all praise.*—Prof. FRANCESCO SINIGAGLIA, *Bollettino del Collegio degli Ingegneri ed Architetti, Naples.*

In this important work the history of the steam-engine, its theory, practice and experimental working are set before us. The theory of the steam-engine is well treated and in an interesting manner. The subject of cylinder condensation is treated at great length. The question of friction in engines is carefully handled, etc., etc. Taken as a whole, these volumes form a valuable work of reference for steam-engine students and engineers.—*Engineering, London, England.*

The volume extends to about 960 pages (including the introductory matter), and forms, with the first part, the most valuable and important addition to the literature of the steam-engine that has been made of recent years. The two volumes, which are beautifully printed in clear, readable type, are splendid specimens of the printer's art; the illustrations are numerous in both books; the binding is excellent; and the whole get up of the work reflects the highest credit on the publishers, who, we anticipate, will have a large demand for the manual. The work is one which we have every confidence in recommending to our engineering friends, especially to all those who desire to acquire the requisite knowledge to enable them to reach the higher grades of their profession, and which can only be attained by a thorough and systematic study of such manuals as the one under notice.—*The Steamship, Leith, Scotland.*



ENGINE READY FOR TRIAL.

THE SIBLEY
JOURNAL OF ENGINEERING.

VOL. VIII. DECEMBER, 1893. No. 3.

IN CORNELL UNIVERSITY

"The leading object shall be, without excluding other scientific and classical studies, and including military tactics, to teach such branches of learning as are related to Agriculture and the Mechanic Arts, in such manner as the legislatures of the States may respectively prescribe, in order to promote the liberal and practical education of Industrial Classes in the several pursuits and professions in life."—[An act donating public lands to the several States and Territories which may provide Colleges for the benefit of Agriculture and the Mechanic Arts, July 6, 1862.]

THERMAL ANALYSIS OF A "TANDEM" COMPOUND ENGINE.*

BY R. H. THURSTON.

In a recent paper, "On the Economics of Automatic Engines," the writer developed at considerable length the principles involved in the study of the thermal distribution in such engines. He illustrated his methods by the computation of the quantities of heat and power utilized and wasted under specified conditions of operation, such as are usual with this class of machines, giving a tabulated statement of the amount of heat-energy supplied, the quantity utilized by conversion iuto dynamic energy, that wasted as heat by conduction and radiation, and that lost by internal transfer without transformation and by other than thermo-dynamic and necessary waste.† In the present paper, the writer proposes to show what is this distribution in an engine of familiar and representative type in good standing among machines of its class, as determined by a careful and fairly complete trial, made by the methods which the writer has been accustomed to employ and in-

*From the *Journal of the Franklin Institute* October, 1893. We are indebted to the Institute for the use of cuts.

†*Jour. Franklin Inst.*, Oct. 1892.

cluding the system of comparative analysis based upon the orginal work of Hirn and of Dwelshauvers-Dery.*

As marked in the paper above referred to:

"The exact expenditure of heat, steam and fuel under specified representative conditions of this case, including steam-pressure, back-pressure, ratio of expansion, and boiler-efficiencies, can be computed for the thermo-dynamic, ideal, case; and, knowing the magnitude and conditions of physical operation of the engine, friction included, its waste of energy, whether thermal or dynamic, can be very closely obtained by computation, and these wastes being added to the total thermo-dynamic expenditure, the gross outlay of energy becomes known and the economical problem can be solved." The following was given in illustration of these methods as determined for an "automatic" simple, condensing, engine, rated at ten to fifteen horse-power; having a cylinder six inches in diameter and eight inches stroke of piston, a speed of 280 revolutions a minute, and proportioned for a steam-pressure of 100 pounds. Compression was assumed complete and leakage insensible.

The demand for heat and steam was computed on the assumption of the data given below; the conditions as to waste being illustrated in the Sandy Hook experiments of 1884.† External wastes were assumed to average 0.5 B. T. U. per square foot of exposed surface, and per degree range of temperatnre from atmospheric—here taken as 100° F. Internal wastes were taken as a fraction of the total steam supplied,

$$w = a/d \cdot \sqrt{rn}$$

where the coëfficient $a = 4$ in the case assumed to be fairly represented of that here considered; d is the diameter of cylinder in inches, r the ratio of expansion, and n the number of revolutions per *second*. Friction wastes were taken as giving an efficiency of engine of 0.85.‡ J is taken as 778. The following are the data:

DATA.

$p_1 =$	75	95	115	135	155
$p_3 =$	5	5	5	5	5
$r =$	1·6	2	4	8	16
$c = \frac{1}{r} =$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{16}$

Manual of the Steam Engine, part i, chaps. v, vi.

†*Ibid.*, chap. v, § 129, p. 501.

‡*Manual of the Steam Engine*, part i, chap. v, § 132—134.

Pressures were measured from absolute zero.

The thermo-dynamic effect of the steam was computed by the equations of Rankine.*

These computations for the ideal case show the consumption of steam under the specified conditions of pressure and cut-off to vary from a minimum of about eleven pounds per horse-power and per hour, at 155 pounds absolute pressure, to fifteen and one-third at the best cut-off for seventy-five pounds. But the introduction of the wastes produced an entirely different showing, and, for this case, the minima were found at expansions approximating

$$r = 0.5\sqrt{p}$$

or from one-seventh at 155 pounds to one-fourth, nearly, at seventy-five pounds above a vacuum, initial pressure in the cylinder; while the steam consumption became about

$$w = 250 \div \sqrt{p}$$

ranging from twenty-three to twenty-eight pounds per indicated horse-power per hour, and twenty-seven to thirty-three pounds per dynamometric horse-power.

In the case here to be presented, the engine is a compound, is much larger and more powerful, and affords better opportunity to effect this approximation. Its dimensions are:

DIMENSIONS OF ENGINE.

Diameter of high-pressure cylinder	12	inches.
Diameter of low-pressure cylinder	20	inches.
Length of stroke (nominal)	14	inches.
Length of stroke (measured)	13·97	inches.
Diameter of piston rod	1.9375	inches.
Area of high-pressure piston, head	113·098	square inches.
Area of high-pressure piston, crank	110·149	square inches.
Area of low-pressure piston, head	311·211	square inches.
Area of low-pressure piston, crank	311·211	square inches.
Piston displacement, high-pressure, head	·91425	cubic foot.
Piston displacement, high-pressure, crank	·89042	cubic foot.
Piston displacement, low-pressure, head	2·51575	cubic feet.
Piston displacement, low-pressure, crank	2·51575	cubic feet.
Clearance, high-pressure cylinder, head	·15716	cubic foot.
Clearance, high-pressure cylinder, crank	·14718	cubic foot.
Clearance, low-pressure cylinder, head	·31422	cubic foot.
Clearance, low-pressure cylinder, crank,	·31925	cubic foot.

**Rankin's Prime Movers; Thurston's Manual*, p. 398; and chap. V, § 137.

Clearance, per cent. of stroke, high-pressure cylinder, head	17·50	
Clearance, per cent. of stroke, high-pressure cylinder, crank	16·20	
Clearance, per cent. of stroke, low-pressure cylinder, head	7·40	
Clearance, per cent. of stroke, low-pressure cylinder, crank	7·60	
Volume of receiver-space	1·1455	cubic feet.
Volume of space in pressure-plate	·12819	cubic foot.
Volume of space in pressure-plate, per cent. of stroke	5·09	

The design and arrangement of the engine is shown well in the plate exhibiting the method of fitting up for trial, and need not be here described.* It was built by the inventor, Mr. A. L. Ide, and is a "tandem compound" of the style known to the trade as "the Ideal." The computations of probable wastes, on the assumed basis previously taken, of correspondence with those of the Sandy Hook experiments, would give figures, reduced to expenditures per horse-power and per hour, about one-half those of the smaller engine above referred to, with its six-inch cylinder,† and would, on that basis and with ten per cent. friction, be as follows :

At the lowest pressure, 75 pounds, with the engine alluded to, maximun economy of steam and fuel was found at a cut-off very near $\frac{7}{32}$, or a ratio of expansion of about 4·5, when the dynamometric power was taken, or at about a cut-off of 0·2 and $r = 5$, on the basis of indicated power. These figures became about 3·16 and 5 at 95 pounds, $\frac{11}{64}$ and 6 at 115, $\frac{5}{32}$ and 6·4 at 135, and $\frac{9}{64}$ and 7 when the pressure was 155 absolute, or 140 pounds by gauge.

The minimum cost of power, in steam consumed, remains not far from the cut-offs identified for the first representative case ; but the computed weights demanded are reduced very considerably by the fact that the wastes are but about one-half those previously found for the smaller engine. These wastes averaged eight or nine pounds for the latter, and are about four and one-half for the former.‡ It will be interesting now to compare these computed results with the actual performance of the machine. A single trial will suffice, as it will establish the constants for the engine,

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* For details of method, see *Thurston's Engine and Boiler Trials*, or *Carpenter's Experimental Engineering*.

† See *Manual*, chap. v, vi.

‡ For details, see *Manual of the Steam Engine*, part i, art. 35, p. 142.

and the behavior of the machine for other conditions than those of the trial may be then computed with satisfactory approximation, as required or desired.

EXTRA-THERMO-DYNAMIC WASTES.

*Total Consumption of Steam.**

r	Cut-off.	Pressure, Lbs. per sq. in.	Steam per I.H.P. per Hour (Ideal) W.	Total Waste, Lbs. per I.H.P. and per Hour.	Total Consumption, Lbs. per I.H.P. and per Hour.	Same per D.H.P. Machine Eff., 0·90.
16	1–16	75	15·85	11·5	27·35	30·6
8	1/8	75	15·32	7·5	22·82	25·4
4	1/4	75	16·72	5·5	22·22	26·7
2·7	3/8	75	18·48	5·3	23·78	26·4
2	1/2	75	21·44	5·3	26·74	29·7
1·6	5/8	75	24·76	5·2	29·96	33·3
16	1–16	95	12·74	8·7	21·44	23·8
8	1/8	95	13·21	6·2	19·41	21·6
4	1/4	95	15·42	4·8	20·26	22·5
2·7	3/8	95	17·72	4·7	22·42	22·7
2	1/2	95	20·34	4·6	24·14	27·0
1·6	5/8	95	23·11	4·6	27·71	30·8
16	1–16	115	11·91	8·0	19·91	22·1
8	1/8	115	12·68	5·9	18·58	20·6
4	1/4	115	14·97	4·8	19·77	22·0
2·7	3/8	115	17·35	4·6	21·95	24·4
2	1/2	115	19·88	4·5	24·38	27·1
1·6	5/8	115	22·60	4·0	26·60	29·9
16	1–16	135	11·38	7·5	18·88	21·0
8	1/8	135	12·32	5·6	17·92	19·9
4	1/4	135	14·67	4·7	19·37	21·5
2·7	3/8	135	16·96	4·4	21·36	23·7
2	1/2	135	19·54	4·4	23·94	26·5
1·6	5/8	135	22·25	4·4	26·65	29·6
16	1–16	155	10·98	7·1	18·08	20·1
8	1/8	155	12·05	5·5	17·55	19·5
4	1/4	155	14·41	4·6	19·01	21·0
2·7	3/8	155	16·72	4·4	21·12	21·1
2	1/2	155	19·28	4·3	23·58	25·1
1·6	5/8	155	21·95	4·1	26·05	28·9

* The mean effective pressure here found is as before, not far from

$$p_2 = 6\sqrt{p_1}$$

and the pressure to be adopted by the designer for such cases will be greater, perhaps not far from

$$p_2 = 5\sqrt{p_1}$$

gauge-pressures being taken; while the power of the engine is, for the best cases,

$$I.H.P. = 0{\cdot}025\, d^2 \sqrt{p_1}, \text{ nearly,}$$

slowly rising with increasing pressure; *d* being here the diameter of the large cylinder,

$$D.H.P. = 0{\cdot}022\, d^2 \sqrt{p_1}, \text{ nearly.}$$

The following are the results:

DATA AND RESULTS.

Time of starting	6.45 P. M.
Time of stopping	11.45 P. M.
Duration of trial	5 hours.
Total number of revolutions (per continuous counter)	60,300
Revolutions per minute	201
Barometer in inches of mercury	29·40
Atmospheric pressure	14·50 pounds.
Boiling temperature at atmospheric pressure	211°·10
Boiler pressure by gauge	98·00 pounds.
Boiler pressure, absolute	112·50 pounds.
Pressure in steam chest, low-pressure cylinder	34·00 pounds.
Vacuum gage, inches of mercury	22·99
Temperature of condensed steam	130°·8
Temperature of injection water	47°·9
Temperature of discharge water	106°·7
Temperature in calorimeter, steam pipe	212°·8
Quality of steam in steam pipe	95·50 per cent.
Quality of steam in compression (assumed)	100·00 per cent.
Quality of steam in exhaust	93·30 per cent.
Total weight of condensed steam	11594·50 pounds.
Pounds of wet steam per stroke, mean	·0961484
Pounds of wet steam per stroke, head	·103593
Pounds of wet steam per stroke, crank	·088704
Cubic feet of condensing water per minute (by meter)	9·304
Pounds per revolution	3·033
Pounds per stroke, head	1·634
Pounds per stroke, crank	1·399
Length of brake arm	8·07 feet.
Gross weight on brake scale	367. pounds.
Net weight on brake scale	323·75 pounds.
Available delivered horse-power	99·99

The brake could not measure all power delivered from the engine, as the engine drove the air-pump arrangement; and this was separately measured by employing an electric motor, when it was found that the power absorbed by the pump was 0.7 horse-power, and, with its accessories when at work, 1.18 horse-power,

giving as a total D.H.P. 101.17 horse-power, and a machine-efficiency, for the engine itself, of 90.16 per cent. The engine was new and had not been smoothed up by work.

The indicator cards were measured by planimeter. The following are the average mean effective pressures and corresponding power:

	Head.	*Crank.*	*Total.*
M.E.P., high-pressure cylinder	30·096	26·460	—
M.E.P., low-pressure cylinder	16·854	13·729	30·579
I.H.P., high-pressure cylinder	24·132	20·664	44.796
I.H.P., low-pressure cylinder	37·188	30·294	67·482
Total I.H.P.			112·28
Total D.H.P.			101·17
Efficiency per cent.			90·16
Total weight of wet steam			11595.50 pounds.
Weight of wet steam per hour			2319·10 pounds.
Weight of dry steam per hour			2234·72 pounds.
Weight of steam per I.H.P. per hour			*19·903* pounds.
Weight of steam per D.H.P. per hour			*22·35* pounds.

The indicator diagrams were found to be sufficiently well taken and finely drawn to permit the application to the case of the methods of Hirn and Dwelshauvers-Dery; the quantity and quality of the steam at every instant in the cylinder being determinable, and the measures of heat transformed and heat transferred without transformation being readily obtained by comparison with the data secured from the observations of boiler performance and steam-supply. Hirn's principle, as here applied, reads thus: "Between any two positions of the piston, the quantity of heat, which has done external work, and that which is exchanged between the metal and the steam, form a sum equal to the difference between the amount of heat in the steam in those positions; increased (if necessary) by the heat that may have been introduced with new steam, or diminished by that which may have left the cylinder."

* * * * * * * *

The losses of heat result in the condensation of steam in such quantity as may be required to supply that heat from its stock of "latent" heat or stored energy, in potential form, and correspondingly reduced volume of working fluid. These losses consist of*

* *Manual*, chap. v.

(1) Heat transformed into work by thermo-dynamic action.

(2) Heat wasted by the unavoidable thermo-dynamic loss at the end of expansion.

(3) Heat lost by conduction and radiation from the exterior of the cylinders and passages.

(4) Heat wasted by absorption into the metal of the cylinder, and later, returned to the steam and rejected with it into the condenser without doing useful work.

The compound engine has the advantage of reducing this last waste; while it exaggerates the third of the series. It reduces the last, however, so greatly as more than to compensate the exaggerated loss by external conduction and radiation—provided it is properly proportioned—and permits, thus, the adoption, economically, of a larger ratio of expansion and the securing of higher efficiency than would otherwise be practicable, by the reduction of the second form of waste above enumerated, with consequent increase of the proportion usefully transformed under the first head of our category. In "receiver engines," wastes by conduction and radiation from the intermediate receivers, as well as from the added cylinders, tend to reduce the gain from restriction of internal wastes.* The application of the Hirn system of study to this case involves the determination of the condition of the working fluid as it traverses these receivers and the intermediate steam-passages, as well as at entrance into the high-pressure cylinder and at exit into the condenser. A steam gauge and a calorimeter provide the means of obtaining the desired data at each of these points. It still remains uncertain, usually, just in what proportion the water carried by the steam is shared between the two ends of the cylinder; and it must generally be assumed that it is divided between them in proportion to steam taken by each.

The data obtained, in the present case, from the trial here referred to are as follows:

HIRN'S ANALYSIS—DATA.

High-pressure Cylinder.

	End.	
	Head.	*Crank.*
Cut-off, per cent. of stroke.	26·40	19·83
Release, per cent. of stroke,	75·17	62·91
Compression, per cent. of stroke,	12·56	12·56
Absolute pressure at cut-off,	105·30	104·50
Absolute pressure at release,	56·00	49·00

**Manual*, chap. vi.

Absolute pressure at compression, ...	49·00	46·00
Absolute pressure at admission, ...	73·00	81·00
Volume in cubic feet, at cut-off, ...	·40045	·32673
Volume in cubic feet, at release, ...	·76313	·70351
Volume in cubic feet, at compression, ...	·27210	·25903
Volume in cubic feet, at admission, ...	·15716	·14718
External work B.T.U., admission, ...	4·9000	3.5958
External work B.T.U., expansion, ...	5·0681	4·8380
External work B.T.U., exhaust, ...	3·4571	2·5497
External work B.T.U., compression, ...	1·2419	1·2749
External work B.T. U., total, ...	5·2692	4·6092
Steam from boilers, pounds, ...	10·3593	8·8704
Steam in clearance, pounds, ...	2·6906	277·91
Steam, total, pounds, ...	13·0499	11·6495
Heat in exhaust, ...	11373·70	9738·80
Heat supplied to engine, ...	12220·95	10316·00
Sensible heat at admission, ...	741·45	785·99
Internal heat at admission, ...	2207·16	2264·20
Sensible heat at cut-off, ...	3940·42	3510.80
Internal heat at cut-off, ...	7747·50	6279·00
Sensible heat at release, ...	3363·00	2901·30
Internal heat at release, ...	8490·55	6959·30
Cylinder loss during admission, ...	2991·64	3216·82
Cylinder loss during expansion, ...	672·44	554·60
Cylinder loss during exhaust, ...	2535·37	2737·76
Cylinder loss during compression, ...	536·51	181·83

Low Pressure Cylinder.

	End.	
	Head.	*Crank.*
Cut off, per cent. of stroke, ...	36·18	24·48
Release, per cent. of stroke, ...	88·23	87·72
Compression, per cent. of stroke, ...	33·82	22·80
Absolute pressure at cut-off, ...	25·50	26·50
Absolute pressure at release, ...	12·00	9·70
Absolute pressure at compression, ...	3·00	3·00
Absolute pressure at admission, ...	22·00	19·00
Volume in cubic feet at cut-off, ...	1·2209	·92491
Volume in cubic feet at release, ...	2·3974	2·3752
Volume in cubic feet at compression, ...	1·0359	·76953
Volume in cubic feet at admission, ...	·3142	·3192
Volume in cubic feet of space in pressure plate, . .	·12819	·12819
External work B.T.U., admission, ...	5·4233	3·5390
External work B.T.U., expansion, ...	4·1360	3·3582
External work B.T.U., exhaust, ...	·4109	·5811
External work B.T.U., compression, ...	1·5339	·9773
Total, ...	7·6146	6·3388
Steam from boiler, pounds, ...	10·3593	8·8704
Steam clearance, pounds, ...	1·7418	1·5387

Steam, total, pounds,	12·1011	10·4091
Heat of condensed steam,	1023·50	876·40
Condensing water, pounds,	108·937	93·279
Heat given to condensing water,	9608·30	8227·20
Heat supplied to engine,	11373·70	9738·80
Sensible heat at admission,	351·51	298.39
Internal heat at admission,	1528·00	1362·50
Sensible heat at cut-off,	2599·20	2208·30
Internal heat at cut-off,	6768·20	5324·50
Sensible heat at release,	1980·00	1611·70
Internal heat at release,	6783·50	5694·20
Total heat in steam at beginning of compression,	935·66	695·07
Heat confined in pressure plate,	521·69	465·36
Cylinder loss during admission,	3343·48	3512·99
Cylinder loss during expansion,	331·39	674·28
Cylinder loss during exhaust,	2763·37	2434·66
Cylinder loss during compression,	268·77	402·73

Summary of Results.

High-Pressure Cylinder.

	End.	
	Head. Per Cent.	*Crank. Per Cent.*
Heat lost by initial condensation,	24·48	31·18
Heat restored during expansion,	5·50	5·38
Heat rejected during exhaust,	20·75	28·11
Heat lost during compression,	4·39	1.76
Heat utilized, work (actual efficiency),	4·31	4·47
Thermo-dynamic efficiency,	8·77	8·77
Efficiency compared with ideal,	49·10	50·90
Quality of steam entering (per calorimeter).	95·50	95·50
Quality of steam at cut-off (computed),	74·19	67·33
Quality of steam at release (computed),	78·01	71·07
Quality of steam at admission (assumed),	100·00	100·00
Quality of steam in exhaust (computed),	104·00	104·00

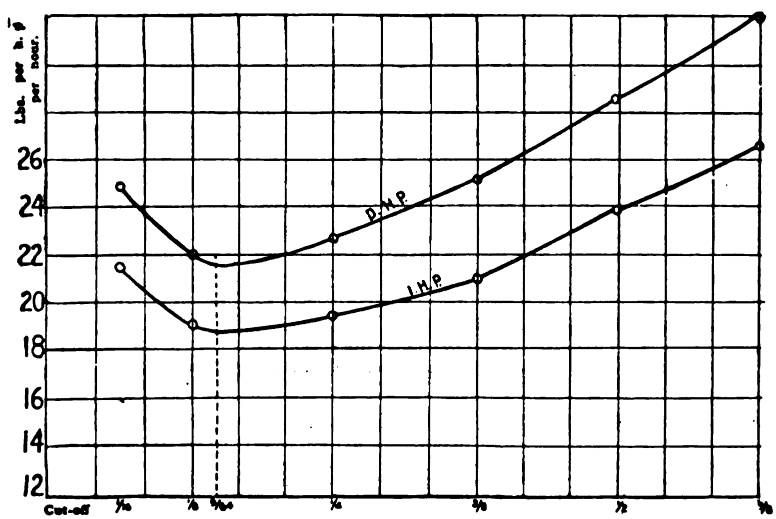
Low-pressure Cylinder.

Heat lost by initial condensation,	29·40	36·07
Heat restored during expansion,	2·91	6·92
Heat rejected during exhaust,	24·30	25·00
Heat lost during compression,	2·36	4·13
Heat utilized, work (actual efficiency),	6·69	6·51
Thermo-dynamic efficiency,	15·66	15·66
Efficiency compared with ideal,	42·70	41·56
Quality of steam entering (per calorimeter),	93·30	93·30
Quality at cut-off (computed),	64·22	50·63
Quality at release (computed),	64·76	54·00
Quality at admission (assumed),	100·00	100·00
Quality of steam in exhaust (computed),	90·12	102·00

Averaging the given values for the head and crank ends for each of the two cylinders, the following values are obtained :

	Cylinders.		
	H.P. Per Cent.		L.P. Per Cent.
Quality of steam entering (per calorimeter), . . .	95·50		93·30
Quality of steam at cut-off (computed), ...	70·76		57·42
Quality of steam at release (computed), ...	74·54		59·38
Quality of steam at admission (assumed), ...	100·00		100·00
Quality of steam in exhaust (computed), ...	104·90		96·06
Heat lost by initial condensation, ...	27·83		32·73
Heat restored during expansion, ...	5·44		4·91
Heat rejected during exhaust, ...	24·43		24·65
Heat lost during compression, ...	3·07		3·24
Heat utilized, *work* (actual efficiency), ...	4·39		6·60
Total, ...		10.99	
Thermo dynamic efficiency, ...	8·77		15·66
Total.		24.43	
Efficiency compared with ideal, ...	50·00		42·13
Mean, ...		46·07	

Losses by external radiation could not be measured and set apart ; but the engine cylinders were well covered and lagged, and this loss may be estimated as about five per cent. The engine was operated under unfavorable circumstances, such as an under-load and an insufficient supply of condensing water, hence the value for efficiency obtained is somewhat lower than is often obtained in practice.



STEAM CONSUMPTION—COMPOUND ENGINE.

Comparing these results with the computations given in the opening portion of this paper, it is seen that the total ratio of expansion was here not far from that found most economical in the earlier investigation, and that the consumption of steam is in close accord with the figures there obtained and the duty substantially as shown in the accompanying curve.

The deduction thus to be drawn is that the constants assumed in the tabulated work are substantially correct for an engine of this class, of good design and construction and operated under ordinarily favorable conditions. The table of engine efficiencies given above may therefore be taken as a probably safe guide in the design of such engines, assuming that correct proportion of volume of cylinders and the best ratios of expansion are adopted for the cases to be met. These proportions are never those found to give minimum cost of steam and fuel, however, and are always such as will exact lower ratios of expansion and smaller ratios of cylinder volumes than those giving maximum fuel economy and highest engine duty. Just to what extent this discrepancy will exist will be determined by costs of engine and of value of fuel and attendance. The best figure is usually two-thirds or three-fourths the value of these ratios, as identified by the processes here described.

The general facts of the case are that the high-speed engine, with its positive valve motion, its single valve system and its usually large clearances, notwithstanding its advantage of high speed of piston and of rotation, gains enough by compounding to barely compensate the losses due those features which, though having special advantage mechanically, are sources of loss thermodynamically. It thus happens that the same process of computation of wastes being resorted to, the constants employed may be substantially the same as those obtained by experiment from the older type of four-valve, detachable gear, with its lower speed and smaller clearances, and in some respects its better steam distribution. These methods and constants, here found applicable to this engine by test, will presumably apply to other engines of the same class and type under similarly favorable conditions, and may be employed in computation of probable wastes and utilized energy by the designer of such machines, and in the solution of problems involving new conditions, for which results of actual experience are not available. They are to be applied with caution, however, until fully confirmed by repeated and extended investigations, and are to be taken as representative, for

the time at least, of limits of expansion for the best makes and best conditions of operation of compounded high-speed engines. In ordinary practice, lower ratios of expansion and higher mean pressures will be found best. Larger engines will give a somewhat lower curve than that shown in Fig. 2; smaller or more wasteful engines will give a higher locus for the curve.

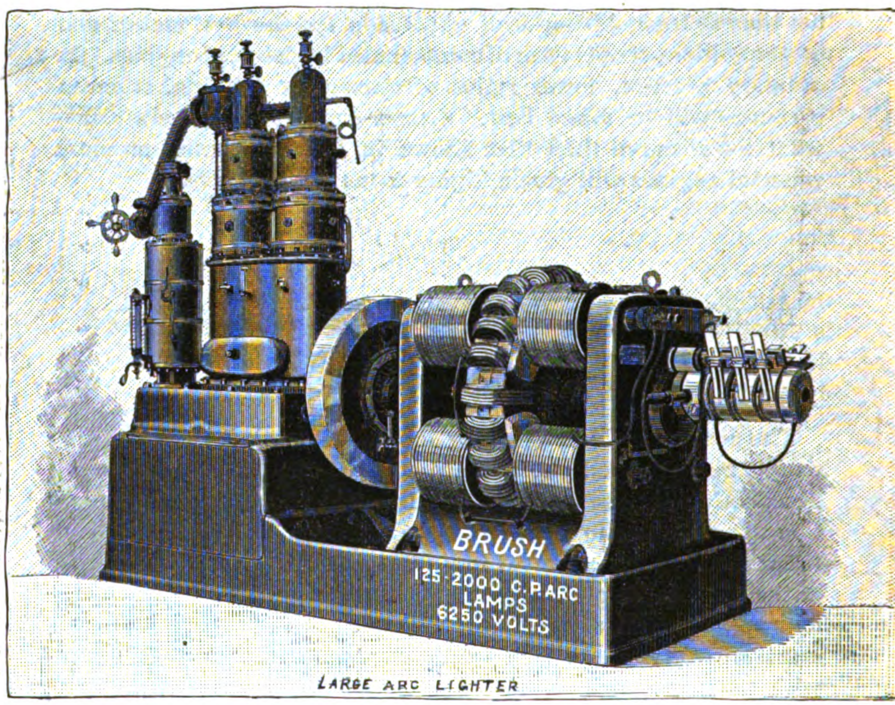
DIRECT COUPLED ARC LIGHTING MACHINERY.*

BY S. B. FORTENBAUGH, '90.

The accompanying engraving shows the Brush Electrical Company's new 125 arc light machine coupled direct to a Willians engine, both being mounted on the same bed plate. It is our intention to present a short description of the dynamo and engine, and the results of a test made for the judges of the electrical department at the Worlds Fair during the past summer. The dynamo is a four pole machine of the Gramme ring, open coil type, and the armature is cross connected so that only one set of brushes is used with the three ring commutator, each ring having eight segments.

The armature has 24 bobbins, each having 528 turns of No. 12 wire—resistance 19.8 ohms—and the field cores are each wound with 1,560 turns of No. 8 wire—resistance 20.3 ohms. The size of the wire used is such that, when the machine is working at full load, the current density is only 1,775 amperes per sq. in. of copper in the armature and 750 in the fields. The frame is cast iron, the magnet cores and pole shoes are one casting of soft steel, and the completed machine weighs about 9,500 lbs. It has a base that is 38x44 inches and the machine is 4 feet high. The machine runs extremely "quiet" at the commutator and requires very little adjustment of the brushes throughout the entire range of load. These facts—together with the excellent ventilation and good mechanical design—make the machine a great commercial success.

* We are indebted to *Power* for the cut of the sectional view of the engine, to the Brush Electric Co. for the cut of the engine and dynamo coupled together, and to the M. C. Bullock Co. for the cut of the air cushion curve.



ENGINE AND DYNAMO.

It was designed by Mr. S. H. Short, and has a commercial efficiency of 89 per cent., at a speed of 525 revolutions per minute.

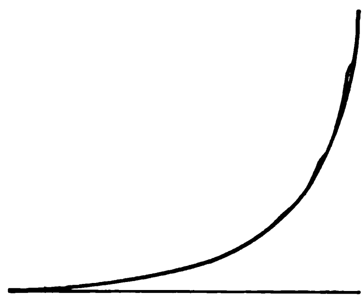
The Willans central-valve engine is a single acting, vertical engine, having all its brasses constantly in compression. Each line of pistons is connected to its corresponding crank by two exactly similar connecting rods, with a space between them, in which works an eccentric, forged solid upon the crank-pin.

Piston valves are used, moving inside a hollow piston-rod, which passes completely through the line of pistons, and through the ends of the cylinders. The reason the eccentric is on the crank-pin, and not on the shaft as usual, is that the valve-face moves with the pistons. The required valve motion is a motion relative to the pistons and this is obtained by mounting the eccentric on the crank-pin, which, like the piston-rod, moves up and down with the pistons. The brasses and eccentric straps dip bodily into the lubricant—oil and water mixed—in the crank chamber at every revolution, and splash it over the main bearings, connecting and eccentric rods, and into the guide cylinders, so

that the lubrication of the working parts—other than the steam pistons and valves—is entirely automatic.

Steam—after first having passed through the separator—enters the high pressure cylinder from the chest on top through the narrow portion of the upper valve, as indicated by the arrows, and is exhausted through the hollow piston rod into the space below the high pressure cylinder, known as the receiver. The distribution with reference to the low pressure cylinder is the same, except that the steam is taken from the receiver and exhausted into the atmosphere or the condenser. The water above each piston is swept downwards by the exhaust steam into the space below during the whole of the exhaust stroke, thus providing good drainage aside from the action of the relief-valves.

The point of cut-off is fixed, and regulation is effected by a throttling governor operated by the revolving weights mounted upon the shaft. From the indicator diagrams we see that very little compression is given in the steam cylinders, the required cushioning being obtained independently by the guide pistons.



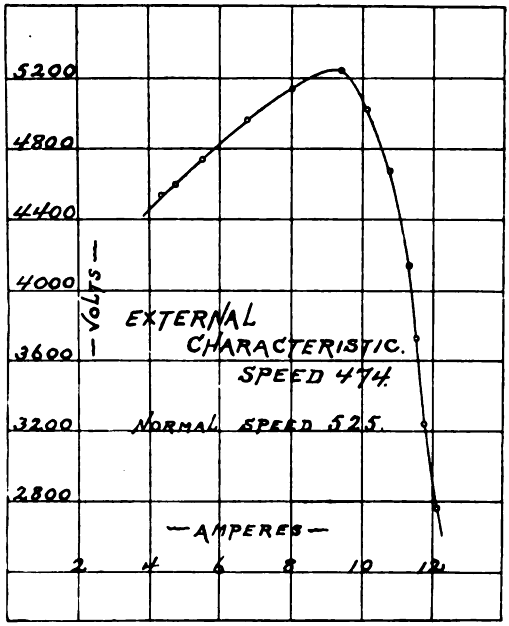
AIR-CYLINDER DIAGRAM.

These, on the up-stroke, compress the air contained in the guide cylinders, and thus any desired amount of cushion can be obtained by varying the clearance.

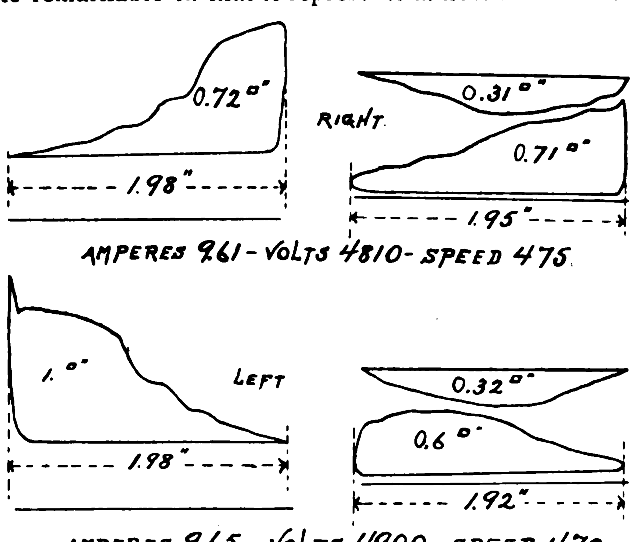
We have here a diagram taken from the air-cushion cylinder, which shows that the work expended in compressing the air is given out again by its expansion on the succeeding down stroke without appreciable loss. The chamber surrounding the guide cylinders is open to the atmosphere, and therefore, the air compression always commences at atmospheric pressure, and is constant and invariable in results, whatever attractions may be made in the pressure of the exhaust steam.

The cuts here given show an external characteristic of the dy-

namo and a complete set of indicator cards with the corresponding electrical data at the time of taking the cards. The charac-



teristic was taken with the brushes at the sparkless position and is quite remarkable in that it represents almost an ideal one and



CARDS FROM WILLANS ENGINE.

shows to what degree perfection has been obtained in this particular machine.

Turning now to the indicator cards we find three distinct areas, representing the work done in the high and low pressure cylinders and the receiver of the low pressure cylinder. The cards from the high and low pressure cylinders are of the usual form, but it might be well to explain the card from the receiver. Beginning at the end of the down stroke, and continuing throughout the up stroke, we have the same pressure on both sides of the high pressure piston, *i. e*, the receiver pressure. During the down stroke, admission to the low pressure cylinder, from the receiver, causes the pressure on the under side of the high pressure piston to be less than it was on the up stroke, and therefore, the card represents the work done in the receiver. In presenting the results it should be stated that the combination had run but a few hours with a small load, and therefore, the bearings were somewhat stiff. The engine data are as follows: Area of low pressure piston 141.37 sq. ins.—Constant for high pressure piston .505—Constant for receiver piston .466—High pressure cylinder spring 100 lbs.—Low pressure cylinder spring 50 lbs.—Stroke 6 inches. The receiver volume varies from a minimum of 395.84 cubic inches at the top of the stroke to a maximum of 918.284 cubic inches at the bottom. A number of cards were taken from which we obtain the following averages:

Average electrical horse-power	62.7
" indicated "	88.8
Combined commercial efficiency	70.6 per cent.

—The U. S. Naval vessels "New York," "Olympia," "Columbia," have made some very remarkable records, of late. They have logged, respectively, 21.07, 22.25, and 22.8 knots, developing, in the case of the New York, 17,000 indicated horse power, and in that of the Columbia 21,500. The coal consumption at these high powers and speed, is enormous, both in the aggregate and as referred to the horse-power. The "New York" consumed 3.95 pounds of coal per horse-power per hour at maximum speed. Merchant vessels are more economical at their maximum powers, usually, than naval vessels. The "Lucania" made 22.5 knots with 30,000 horse power, and consumed but 480 tons of coal per day, or about 1.5 pounds per horse-power per hour.

SAMPLE PROBLEMS IN THERMODYNAMICS.

The following sample problems in thermodynamics are presented as illustrating the methods and principles of computation of efficiencies and of heat and fuel demanded in the useful transformation of heat into work in the heat-engines employing the permanent gases as their working substances, wholly or mainly. The methods adopted are those employed in the work of the senior class and graduate students pursuing this study in the Department of Mechanical Engineering, and such as are taught in the lectures in this department and adopted in Thurston's "Manual of the Steam-Engine," and in Rankine's "Prime Movers." The problems here presented are given as good examples of the application of these methods, simply. The data and computations are given as purely illustrative and not as exemplifying any actual case. For such cases, see Thurston's "Engine and Boiler Trials," Clerk on the Gas-Engine, and other works containing results of trials of such engines.

PROBLEM I.

Select probable and original numerical values of the quantities entering the problem and determine variations of pressure, temperature, and volume, the heat expended and the net work performed, in working a gas through a Carnot Cycle. Compute efficiency and quantity of heat and fuel per horse power per hour. Call efficiency 90 per cent and determine the same quantities per developed horse power. (What kind of engine could these work?)

In working a gas through a Carnot Cycle, a quantity of gas is taken into the cylinder at A, and is compressed at constant temperature to the point B. Here the gas is further compressed to the point C without receiving or rejecting heat, that is, adiabatically. It is next expanded at constant temperature to the point D, and from D back to the starting point, A, it is expanded adiabatically.

For the first problem we will make the following assumptions:
Suppose that $T_a = T_b = 500°$ absolute temperature.
Let $T_c = T_d = 800°$ absolute temperature.
Let $P_a = 2160$ pounds per square foot.

Ratio of expansion $= \frac{V_a}{V_b} = \frac{V_d}{V_c} = 2.$

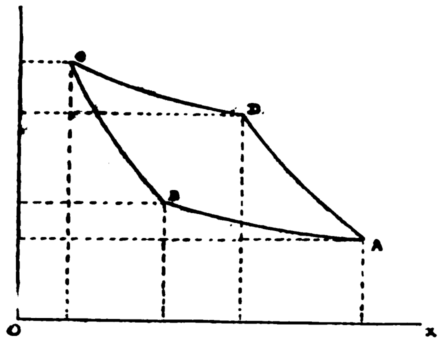


FIG. 1.—*Carnot Cycle.*

Take the heat of combustion of one pound of fuel as 14199 B. T. U.

Assume that we have one hundred cycles per minute, and that we use one pound of gas.

From the defining equation of a perfect gas we have, (see Manual, page 419):

$$\frac{P\,V}{T} = R = 53.15,$$

or for the point A we have

$$\frac{P_a\,V_a}{T_a} = R\,; \quad V_a = \frac{R\,T_a}{P_a}, = \frac{53.15 \cdot 500}{2160} = 12.3.$$

$\therefore\ V_a = 12{\cdot}3\,;\ T_a = 500\,;\ P_a = 2160.$

From A to B we have isothermal compression and

$$V_b = \frac{V_a}{2} = \frac{12.3}{2} = 6.15.$$

$P_b = 2\,P_a = 2160 \times 2 = 4320,\ T_b = 500°.$

$\therefore\ V_b = 6.15\,;\ T_b = 500°\,;\ P_b = 4320.$

From B to C we have adiabatic compression and

$$P_c = P_b \div \left(\frac{T_b}{T_c}\right)^{\frac{\gamma}{\gamma-1}} = 4320 \div \left(\frac{500}{800}\right)^{3.45} \quad \text{or}$$

$\log P_c = \log P_b - 3.45\,(\log .625)$, from which

$P_c = 21860.$

$$V_c = \frac{R \cdot T_c}{P_c} = \frac{53.15 \times 800}{21860} = 1.945.$$

$T_c = 800°.$

From C to D we have isothermal expansion:

$V_d = 2 \cdot V_c = 1.945 \times 2 = 3.89.$

$$P_d = \frac{R \cdot T_d}{V_d} = \frac{53.15 \times 800}{3.89} = 10930.$$

$\therefore\ V_d = 3.89\,;\ T_d = 800\,;\ P_d = 10930,$

From D to A we have adiabatic expansion and

$$P_a = P_d \div \left(\frac{T_d}{T_a}\right)^{3.45}, \qquad \text{(Man. p. 364.)}$$

or,
$$P_a = 10930 \div \left(\frac{800}{500}\right)^{3.45} = 2160$$

which is the same value as assumed at the start, and this is a *check* on the work.

Heat is taken up in passing from C to D and $H = P_c\ V_c \log_e r$, or
$H = 21860 \times 1.945 \times \log_e 2$
$= 29470$ foot pounds. (Man. § 96.)

Heat is expended in passing from A to B,

$$H = P_a\ V_a \log_e \frac{1}{r}, \text{ or} \qquad \text{(Man. § 96.)}$$

$= 2160 \times 12.3 \times \log_e .5 = 18420.$

Net work done $= 29470 - 18420 = 11050$.

$$\text{Efficiency} = \frac{11050}{29470} = 37.5 \text{ per cent.}$$

In the Carnot Cycle the efficiency is

$$\text{Eff.} = \frac{T_c - T_a}{T_c} = \frac{800 - 500}{800} = \frac{300}{800} = 37.5 \text{ per cent.}$$

$$\text{Horse-power} = \frac{11050 \times 100 \times 1}{33000} = 33.48.$$

British Thermal Units per hour

$$= \frac{29470 \times 100 \times 60 \times 1}{778} = 227300.$$

B. T. U. per H. P. per hour

$$= \frac{227300}{33.48} = 6789.$$

Fuel per H. P. per hour

$$= \frac{6789}{14199} = .478$$

pounds of anthracite coal since a pound of coal by combustion produces 14199 B. T. U.

Assuming that the efficiency of machine is 0.90, the delivered H. P. $= 33.48 \times .9 = 30.132$.

B. T. U. per D. H. P. per hour

$$= \frac{227300}{30.13} = 7543.$$

Fuel per D. H. P. per hour

$$= \frac{7543}{14199} = .5312.$$

Taking one pound of coal as the equivalent of the heat losses due to conduction, radiation, etc., we add one pound of coal for each H. P. per hour and 1.11 pounds for D. H. P. per hour as follows:

Fuel per H. P. $= 1 + .478 = 1.478$ pounds.

Fuel per D. H. P. $= 1.11 + .5312 = 1.6412$ pounds.

If we replace the regenerator action of a Sterling engine by adiabatic expansion and compression lines we have an engine working in a Carnot Cycle.

PROBLEM II.

Select probable and original numerical values of the quantities entering the problem and determine variations of temperature, pressure, and volume, the heat expended and the net work performed, when air at V_a is compressed isothermally, expanded at constant pressure, expanded isothermally to inital pressure, compressed to initial state at constant pressure. Compute efficiency and quantity of heat and fuel per horse-power per hour. Call efficiency of machine 0.90, and compute same for D. H. P. What kind of engine could thus work?

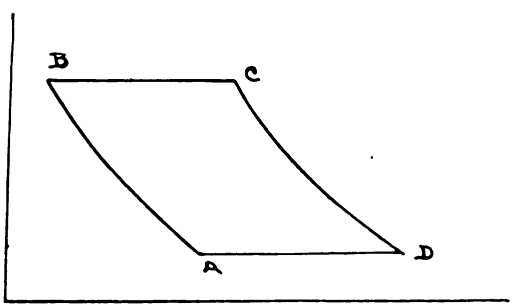


FIG. 2.—*Ericsson Cycle.*

ASSUMPTIONS.

$P_a = 2000$ pounds per square foot.

$T_a = T_b = 600°$ absolute.

90 cycles per minute.

Ratio of expansion

$$r = \frac{V_a}{V_b} = \frac{V_d}{V_c} = 1.5\,;\quad T_c = T_o = 900^\circ,$$

$$V_a = \frac{R\ T_a}{P_a} = \frac{53.15 \times 600}{2000} = 15.9.$$

$\therefore\ V_a = 15.9;\ T_a = 600^\circ,\ P_a = 2000.$

From A to B we have isothermal compression :

$$V_b = V_a \div 1.5 = \frac{15.95}{1.5} = 10.6.$$

$$P_b = \frac{R\ T_b}{V_b} = \frac{53.15 \times 600}{10.6} = 3000.$$

$\therefore\ V_b = 10.6\,;\ T_b = 600\,;\ P_b = 3000.$

From B to C we have expansion at constant pressure, and

$$V_c = \frac{R \cdot T_c}{P_c} = \frac{53.15 \times 900}{3000} = 15.95.$$

$\therefore\ V_c = 15.95\,;\ T_c = 900^\circ\,;\ P_c = P_b = 3000.$

From C to D we have isothermal expansion :

$V_d = V_c \times 1.5 = 15.95 \times 1.5 = 23.9.$

$$P_d = \frac{R \cdot T_d}{V_d} = \frac{55.15 \times 900}{23.9} = 2000.$$

From D to A we have compression at constant pressure, and

$$V_a = \frac{R \cdot T_a}{P_a} = \frac{53.15 \times 600}{2000} = 15.95.$$

Heat is taken up in maintaining the substance at constant pressure from B to C. (Man. p. 418.)

$$H = K_p\,(T_c - T_b).\quad K_p = \frac{\gamma}{\gamma - 1} R = 3.45 \times 53.15 = 183.45.$$

$\therefore$ Heat from B to $C = 183.45\,(900 - 600) = 55035.$

Heat taken up from C to $D = P_c\ V_c \log_e r,$

$= 3000 \times 15.95 \times .405465 = 19400.$

Heat expended or given out from D to A = that taken up from B to $C = 56035.$

Heat given out from A to B

$$H = P_a\ V_a \log_e \frac{1}{r} = 2000 \times 15.95 \times \log_e .66.$$

$= 2000 \times 15.95 \times (- .4064657).$
$= 12925.$

Total heat taken up $= 55035 + 19400 = 64435.$

Total heat given out $= 55035 + 12925 = 57960.$

Net work done $= 64435 - 57960 = 6575.$

$$\text{Efficiency} = \frac{6575}{64435} = 10.2 \text{ per cent.}$$

$$\text{H. P.} = \frac{6575 \times 90 \times .5}{33000} = 8.96.$$

B. T. U. per hour

$$\frac{64435 \times 60 \times 90 \times .5}{778} = 223800.$$

B. T. U. per H. P. per hour

$$\frac{223800}{8.96} = 24981.$$

Fuel per H. P. per hour

$$\frac{24981}{14199} = 1.76 \text{ pounds.}$$

D. H. P. $= .9 \times 8.66 = 8.064.$

B. T. U. per D. H. P. per hour

$$\frac{223800}{8.064} = 27700.$$

Fuel per D. H. P. per hour

$$\frac{27700}{14199} = 1.955.$$

Assuming that the heat losses due to conduction, radiation, etc., are equivalent to the heat produced by the combustion of one pound of coal per H. P. per hour and therefore 1.11 pounds per D. H. P. per hour, we have

Fuel per hour per H. P. $\quad 1.76 + 1 \quad = 2.76$ pounds.

Fuel per D. H. P. per hour $1.95 + 1.11 = 3.06$ pounds.

An engine which has a cycle like that discussed in this problem is the "Ericsson." (See Rankine, p. 354.)

PROBLEM III.

Select probable and original numerical values of the quantities entering the problem, and determine variations of temperature, pressure, and volume, the heat expended and the net work performed, when air is compressed isothermally, heated at constant volume, expanded isothermally, cooled at constant volume to initial state. Compute efficiency and quantity of heat and fuel per horse-power per hour. Call efficiency of machine 0.90 and determine same quantities for D. H. P. What kind of engine would thus work?

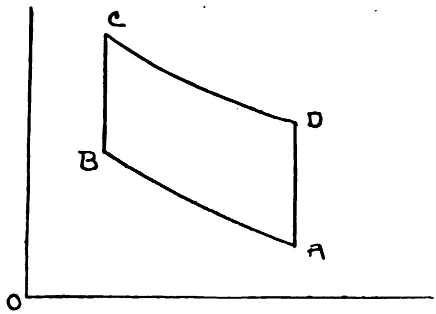


FIG. 3.—*Regenerator Cycle.*

ASSUMPTIONS.

$P_a = 2100$ pounds per square foot.

$r = \frac{V_a}{V_b} = 3, \quad T_a = T_b = 550°$ absolute.

$T_c = T_d = 750°$ absolute.

The engine makes 80 cycles per minute.

$$V_a = \frac{R\ T_a}{P_a} = \frac{53.15 \times 550}{2100} = 13.9.$$

$\therefore\ V_a = 13.9;\ P_a = 2100;\ T_a = 550.$

From A to B air is compressed at constant temperature.

$V_b = \frac{1}{3}\ V_a = \frac{1}{3} \cdot 13.9 = 4.63.$

$$P_b = \frac{53.15 \times 550}{4.63} = 6300.$$

$\therefore\ V_b = 4.63;\ P_b = 6300;\ T_b = 550.$

From B to C the air is heated at constant volume, and

$$P_c = \frac{R\ T_c}{V_c} = \frac{53.15 \times 750}{4.63} = 8600.$$

$\therefore\ V_c = 4.63:\ P_c = 8600;\ T_c = 750.$

From D to A the air is cooled at constant volume, and

$$P_d = \frac{53.15 \times 750}{13.9} = 2865.$$

$\therefore P_d = 2865$; $V_d = 13.9$; $T_d = 750$.

$$P_a = P_d \frac{T_a}{T_d} = 2865 \frac{550}{750} = 2100, \qquad \text{Check.}$$

Heat given out in compressing from A to B

$$P_a V_a \log_e \frac{1}{r} = 2100 \times 13.9 \times (-.693147) = 34700.$$

From B to C the heat taken up is $K_v (T_c - T_b)$. (Man. p. 366.)

$$K_v = R \cdot \frac{1}{\gamma - 1} = 53.15 \times 2.451 = 130.27.$$

$\therefore H = 130.27 \times 200 = 26054$.

In expanding isothermally from C to D the heat taken up is $P_c V_c \log_e r = 8600 \times 4.63 \times 1.0986123 = 43750$.

In passing from D to A the same amount of heat is given out that was taken up from B to C, 26054.

Total heat taken up, $26054 + 43750 = 69804$.

Total heat expended, $34700 + 26054 = 60754$.

Net work, $69804 - 60754 = 9050$.

$$\text{Efficiency} = \frac{9050}{69804} = 12.9 \text{ per cent.}$$

Assuming cylinder charge 0.4 pounds,

$$\text{H. P.} = \frac{9050 \times 80 \times .4}{33000} = 8.77.$$

B. T. U. per hour

$$\frac{69804 \times 80 \times 60 \times .4}{778} = 172000.$$

B, T. U. per H. P. per hour

$$\frac{172000}{8.77} = 19600.$$

Fuel per H. P. per hour

$$\frac{19600}{14199} = 1.38.$$

D. H. P. $= 8.77 \times .9 = 7.893$.

B. T. U. per D. H. P. per hour

$$\frac{172000}{7.89} = 21800.$$

Fuel per D. H. P. per hour

$$\frac{21800}{14199} = 1.53.$$

Making the same assumption as before, *i. e.*, that the losses of heat are 1 lb. per H. P. per hour and 1.11 per D. H. P. per hour, we have,

Fuel per H. P. per hour, $1.38 + 1 = 2.38$.

Fuel per D. H. P. per hour, $1.53 + 1.11 = 2.64$.

An engine working in a cycle such as here described is a Stirling engine, (see D. Clerk, p. 7.)

PROBLEM IV.

Select probable and original numerical values of the quantities entering the problem and determine variations of temperature, pressure, and volume, the heat expanded and the net work done, when an air engine receives heat at constant pressure after adiabatic compression, and rejects it similarly after adiabatic expansion. What kind of engine could thus work?

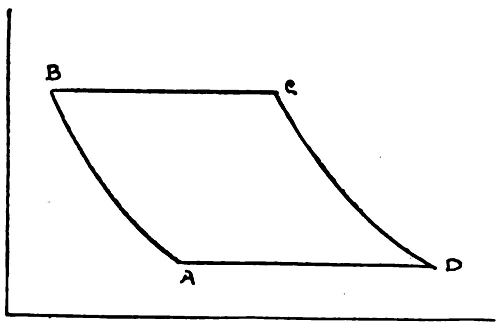


FIG. 4.—*Joule Cycle.*

ASSUMPTIONS.

$P_a = 2200$ pounds per square foot.

$V_a = 15, \quad V_c = 10,$

$$r = \frac{V_a}{V_b} = \frac{V_d}{V_c} = 2.$$

$$T_a = \frac{P_a V_a}{R} = \frac{2200 \times 15}{53.15} = 621.$$

$\therefore \; T_a = 621 \,; \; V_a = 15 \,; \; P_a = 2200.$

From A to B we have adiabatic compression.

$V_b = \frac{1}{2} V_a = 15 \times \frac{1}{2} = 7.5$; $\frac{T_b}{T_a} = \left(\frac{V_a}{V_b}\right)^{\gamma - 1}$

$T_b = 621 \times (2)^{.406} = 824.$

$P_b = \frac{R \cdot T_b}{V_b} = \frac{53.15 \times 824}{7.5} = 5840.$

$\therefore P_b = 5840$; $V_b = 7.5$; $T_b = 824.$

From B to C we have expansion at constant pressure, and

$$T_c = \frac{P_c \ V_c}{R} = \frac{5840 \times 10}{53.15} = 1100.$$

$\therefore P_c = 5840$; $V_c = 10$; $T_c = 1100.$

From C to D we have adiabatic expansion,

$$T_d = \frac{P_d \ V_d}{R} = \frac{2200 \times 20}{53.15} = 828.$$

$\therefore P_d = 2200$; $V_d = 20$; $T_d = 828.$

Heat taken up in passing from B to C

$$K_p \left(T_c - T_b\right) = 183.45 \times 276 = 50642.$$

Heat given out from D to A

$$K_p \left(T_a - T_d\right) = 183.45 \left(-207\right) = -38974.$$

Net work done, $50642 - 37974 = 12668.$

$$\text{Efficiency} = \frac{12668}{50642} = 25 \text{ per cent.}$$

At 90 cycles per minute, and 0.5 pounds per cycle,

$$\text{H. P.} = \frac{12668 \times 90 \times .5}{33000} = 17.3$$

B. T. U. per hour

$$\frac{50642 \times 90 \times 60 \times .5}{778} = 175500.$$

B. T. U. per H. P. per hour

$$\frac{175500}{17.3} = 10150.$$

D. H. P., $.90 \times 17.3 = 15.57.$

B. T. U. per D. H. P. per hour

$$\frac{175500}{15.57} = 11260.$$

Fuel per hour

$$\frac{175500}{14199} = 12.4.$$

Fuel per H. P. per hour

$$\frac{12.4}{17.3} = .716.$$

Fuel per D. H. P. per hour

$$\frac{12.4}{15.5} = .796.$$

Assuming heat losses equivalent to the heat of 1 pound of coal per H. P. per hour and 1.11 per D. H. P., we have

Fuel per H. P. per hour, $1 + .716 = 1.716$.

Fuel per D. H. P. per hour, $1.11 \div .796 = 1.906$.

An engine working in this cycle is a Joule engine. (See Rankine, p. 371.)

PROBLEM V.

Discuss the Brayton or Otto gas-engine cycle. Revise figures on the assumption that a water jacket and the ordinary losses due to conduction and radiation may carry away as waste, the heat equivalent of ten cubic feet of gas per H. P. per hour. In the air-engine assume similar losses equivalent to 1 pound of coal per H. P. per hour.

DISCUSSION OF THE OTTO GAS-ENGINE CYCLE.

This is an explosion engine corresponding to class 3 of D. Clerk, (Theory of the Gas-Engine.) Suppose that the clearance space $O\ E$ is filled with burned gases of the last cycle and let the piston move from E to A drawing in an explosive mixture of air and gas which are now mixed with the gases left in the clearance space. The piston moves back, next compressing the mixture adiabatically along the line $A\ B$, the pressure increasing to B. Here the mixture is ignited and the pressure increases at once to C, a maximum. Expansion now takes place along the line $C\ D$,

the piston moving forward and the pressure dropping to D. Here the exhaust is opened and the piston moves back, expelling the

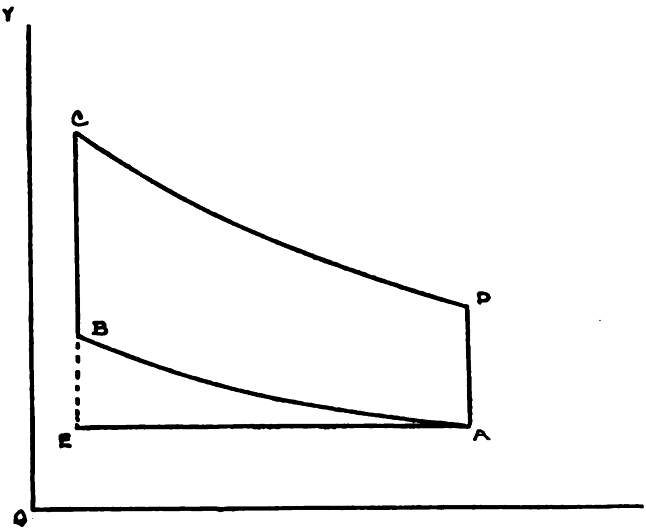


FIG. 5.—*Beau de Rochas Cycle.*

burned gases, to E and the cycle is completed, the clearance space being filled with the burned gases precisely as at the start. It is thus seen that on the diagram four complete strokes are necessary to complete the cycle. In the actual engine the number of strokes per cycle is regulated by the governor and is usually greater, never less than four.

We will make the following assumptions:

$T_c = 2800°$ absolute temperature.

$T_a = 500°$ absolute temperature.

$P_a = 2100$ pounds per square foot.

$$r = \frac{V_a}{V_b} = \frac{V_d}{V_c} = 3.$$

200 revolutions or fifty cycles per minute.

Take $\frac{3}{10}$ pounds of working fluid in cylinder-charge.

$$V_a = \frac{R\,T_a}{P_a} = \frac{53.15 \times 500}{2100} = 12.64.$$

$\therefore\ V_a = 12.64;\ T_a = 500;\ P_a = 2100.$

From A to B we have adiabatic compression,

$V_b = \frac{1}{3} V_a = \frac{1}{3} \cdot 12.64 = 4.21$

$$T_b = T_a \cdot \left(\frac{V_a}{V_b}\right)^{\gamma-1} = 500 \times 3^{.408} = 1025.$$

$$P_b = \frac{R\ T_b}{V_b} = \frac{53.15 \times 1025}{4.21} = 12940.$$

$\therefore\ V_b = 4.21\ ;\ T_b = 1025\ ;\ P_b = 12940.$

From B to C the gas is heated at constant volume,

$V_c = V_b = 4.21,\ T_c = 2800.$

$$P_c = \frac{R\ T_c}{V_c} = \frac{53.15 \times 2800}{4.21} = 35300.$$

$V_c = 4.21\ ;\ T_c = 2800\ ;\ P_c = 35300.$

From C to D the gas expands adiabatically,

$V_d = 3\ V_c = 3 \times 4.21 = 12.64 = V_a.$

$$T_d = T_c \left(\frac{V_c}{V_d}\right)^{\gamma-1} = 2800 \times \tfrac{1}{3}^{.408} = 1788.$$

$$P_d = \frac{R\ T_d}{V_d} = \frac{53.15 \times 1788}{12.64} = 7500.$$

Heat taken up in expanding from B to C,

$$K_v (T_c - T_b)\ ;\ K_v = \frac{1}{\gamma - 1} R = 130.27.$$

$\therefore\ H = 130.27 \times 1775 = 231300.$

Heat given out between D and A

$$K_v (T_d - T_a) = 130.27 \times 1288 = 168000.$$

Net work done, $231300 - 168000 = 63300.$

$$\text{Efficiency} = \frac{63300}{231300} = 27.4 \text{ per cent.}$$

$$\text{H. P.} = \frac{63300 \times 50 \times .3}{33000} = 28.75.$$

B. T. U. per hour

$$\frac{231300 \times 50 \times 60 \times .3}{778} = 267000.$$

B. T. U. per H. P. per hour

$$\frac{267000}{28.75} = 9300.$$

Assuming that 1 cubic foot of gas by its combustion gives out 646 B. T. U., we have

Cubic feet of fuel per hour and H. P.

$$\frac{9300}{646} = 14.4.$$

D. H. P. $= .9 \times 28.75 = 25.875$.

B. T. U. per D. H. P. per hour

$$\frac{267000}{25.875} = 10310.$$

Cubic feet fuel per D. H. P. per hour

$$\frac{10310}{646} = 16.$$

$V_a = 12.64$; $V_b = 4.21$; $V_a - V_b =$ charge $= 8.43$ cubic feet.

B. T. U. per stroke

$$\frac{231300}{778} = 297.$$

Cubic feet gas demanded per stroke

$$\frac{297}{646} = .46.$$

Air per stroke $= 8.43 - .46 = 7.97$.

Ratio of air to gas

$$\frac{7.97}{.46} = 17.3.$$

Allowing 10 cubic feet of gas per H. P. per hour for waste, we have

Cubic feet gas per H. P. per hour, $14.4 + 10 = 24.4$.

Cubic feet gas wasted per hour, $10 \times 28.75 = 287.5$.

Cubic feet gas wasted per stroke

$$\frac{287.5}{60 \times 50} = .0958.$$

Total gas used per stroke, $.0958 + .46 = .5558$.

Volume of air per stroke, $7.97 - .5558 = 7.4142$.

Ratio of air to gas assuming these wastes

$$\frac{7.4142}{.5558} = 13.3.$$

In this problem it was assumed that $\frac{PV}{T} = R = 53.15$ as in the preceding problems.

DISCUSSION OF THE BRAYTON ENGINE CYCLE.

In this cycle, the mixture constituting the charge is adiabatically compressed into a reservoir; thence it issues, burning as it enters, into the working cylinder, expanding to its maximum volume at constant (reservoir) pressure; next, adiabatic expansion takes place to the full volume of the working cylinder, and rejection occurs, first by fall of pressure to atmospheric at constant volume, then with the return stroke of the piston, with constant, minimum, atmospheric pressure. This is distinguished from the Beau de Rochas, or Otto, cycle, by its accession of heat with variation of volume at constant pressure, instead of at constant volume with varying pressure. In this instance, no allowance is made for wastes, which nsually equal the quantities of heat and of gas demanded by the ideal case.

DATA.

Initial temperature (atmospheric), $T_0 = 530.2°$ F.
Initial pressure and maximum at compression,

$$P_0 = 2160 \, ; \quad P_a = 12960.$$

Volume after compression, $V_a = 1$.

RESULTS.

Ratio of increase of pressure by compression,

$$\frac{P_a}{P_0} = \frac{12960}{2160} = 6.$$

Volume at admission,

$$V_0 = \left(\frac{P_a}{P_0}\right)^{\frac{1}{\gamma}} \quad V_0 = 6^{.714} = 3.59.$$

The density of the gas at the temperature of melting ice is $D =$ .0438; or one cubic foot of gas at absolute zero weighs 0.0438 lb. Then take volume gas : total volume :: 1 : 9, since volume air : volume gas :: 8 : 1.

∴ volume gas

$$\frac{\text{total vol.}}{9} = \frac{V_0}{9} = \frac{3.59}{9} = 0.397 \text{ cubic feet,}$$

for D for gas at 32° F., or 493.2° absolute.

∴ weight of cubic ft. of gas at temp. T_0

$$\frac{493.2 \cdot D}{T_0} = 0.0407.$$

Weight, gas alone,

$$\frac{V_0}{9} D' = \frac{3.59}{9} \cdot .0407 \quad 0.016334 \text{ lb.}$$

Weight of air used

$$(3.59 - .397)\underset{\text{ft. air.}}{\overset{\text{Wt. 1 cu.}}{(.0807)}} \cdot \frac{493.2}{530.2} = 0.3024 \text{ lb.}$$

Total weight of mixture $= 0.31863$ lb.

Temperature after compression,

$$T_a = \left(\frac{V_o}{V_a}\right)^{\gamma - 1} \cdot T_o = 833°.$$

Taking 18,000 B. T. U. per pound as the available heat of combustion, $18000 \times 772 = 13,896,000$ foot pounds; energy available from burning 1 pound of coal gas.

The weight of gas used per stroke as above is 0.016334.

$\therefore\ H_1 = 13,396,000 \times .061234 = 225,587.56.$

$K_p = 183.45\ \therefore$

The range of temperature due combustion is

$$T_b - T_a = \frac{H}{WK_p} = 3860°$$

Whence the temperature after combustion,

$$T_b = 3860 + 833 = 4693°.$$

Volume at commencement of expansion,

$$V_b = V_a\left[1 + (T_b - T_a)\frac{1}{833}\right] = 7.8 \text{ cu. ft.}$$

Pressure at beginning of expansion,

$$P_b = P_a = 6 \times 2160 = 12960.$$

Volume at end of expansion,

$$V_o = r \cdot V_b = V_d = 15.6.$$

Temperature after expansion,

$$T_c = \left(\frac{V_b}{V_c}\right)^{\frac{1}{\gamma}} T_b = 3592°.$$

Pressure after expansion,

$$P_c = \left(\frac{V_b}{V_c}\right) \cdot P_b = \frac{12960}{r\,1 - \gamma} = 4910 \text{ lbs. per sq. in.}$$

Where $$r = \left(\frac{P_a}{P_o}\right)^{\frac{1}{\gamma}} = 6^{0.714}$$

Temperature after exhaust,

$$T_d = \frac{P_d}{P_c} \cdot T_c = \frac{2160 \times 610}{4910} = 280°.$$

Pressure,

$$T_d = \frac{2160 \cdot 3592}{4910} = 1573.$$

Heat rejected,

$$H_2 = W \cdot K_p \cdot (T_c - T_o) = 3.186 \times 183 \times 30,609 = 174,800.$$

Work performed,

$$U = H_1 - H_2 = 50787.66.$$

$$\text{Efficiency} = \frac{U}{H_1} = \frac{50787.66}{225,587.66} = 22.5 \text{ per ct.}$$

$$M.\ E.\ P. = \frac{U}{V_3 - V_1} = \frac{50787.66}{15.6 - 1} = 3410 \text{ lbs. per sq. ft.}$$

SUMMARY OF RESULTS.

$\frac{P_a}{P_o} = 6.$

$V_o = 3.59$ cu. ft.

Volume of air $= 0.397$ cu. ft.

Volume of gas $= 0.603$ "

Weight of mixture $= 0.31863$ lbs.

Total weight of air $= 0.3024$ lbs.

$T_a = 833°.$

$V_a = 1$ cu. ft.

$H_1 = 225587.66$ ft. lbs.

$T_b = 4743°.$

$T_c = 3592°.$

$T_d = 280°.$

$V_b = 7.8$ cu. ft.

$V_c = V_d = 15.6$ cu. ft.

$P_a = P_b = 12960$ lbs. per sq. ft.

$= 90$ lbs. per sq in.

$P_c = 4910$ lbs. per sq. ft.

$= 34$ lbs. per sq. in.

$P_d = 2160$ lbs. per sq. ft.

$= 15$ lbs. per sq. in.

$H_2 = 174800$ ft lbs.

Work done $= U = 50787$ ft. lbs.

Efficiency $= 22.5$ per cent.

Mean Effective Pressure $= 3410.11$ lbs. per sq. ft

$= 23.7$ lbs. per sq. in.

SPECIFIC HEAT, HEAT OF COMBUSTION, AIR MIXTURE.

(SAMPLE STUDY).

Composition of the Gas for one lb.			Specific Heat.			
Name of Constituent.	Symbol	Wt.	Cp	C*v*	Cp × Wt.	C*v* × Wt.
Olefiant Gas	C_2H_4	.122	.3694	.2992	.0450668	.0365024
Marsh Gas	CH_4	.529	.5929	.4683	.3136441	.2477307
Carbonic Oxide	CO	.138	.2479	.1768	.0342102	.0243984
Carbonic Acid	CO_2	.069	.2164	.1714	.0149316	.0118266
Hydrogen	H	.081	3.4046	2.4096	.2757726	.1951776
Nitrogen	N	.058	.244	.174	.0141520	.0100920
Oxygen	O	.003	.2182	.1559	.0006546	.0004676
		1.000			.6984319	.5261953
Gas (as above)		.045	.698	.526	.03141	.02367
Air		.955	.238	.169	.22729	.16139
		1.000			.2587	.18506

Volume 1 lb.		Heat of Combustion.	
Vol. 1 lb. each Constituent at 32°. cu. ft.	Vol. × by Wt. cu. ft.	Heat Combust'n for 1 lb. each Constituent.	Heat Comb. × Wt.
12.58	1.534	21343	2603.846
22.135	11.709	24513	12438.377
12.746	1.759	4325	596.85
8.101	.559	000	000.
178.83	14.485	62032	5007.433
12.753	.739	000	000.
11.204	.034	000	000.
	30.819	Deduct from Hydrogen $.003 \times \frac{1}{8} = .000275$	20646.606
At 62° F. we have for vol. $30.819 \times (30 \times .0020276 + 1) = 30.819 \times 1.06 = 32.66$			
32.66	1.4697	20646.	929.1
12.387	11.82958	000.	00.
	13.29928		929.1

RESULTS.

C_p for Mixtnre $= .2597$: $C_v = .18506$
$K_p = .2587 \times 772 = 199.716$
$K_v = .18506 \times 772 = 142.866$
$\gamma = \dfrac{K_p}{K_v}$ 1.396 ; $\dfrac{1}{\gamma} = .709$
$K_p \div D_1 = 199.716 \div 13.3 = 15.01$
$K_v \div D_1 = 142.866 \div 13.3 = 10.74$
$D_1 \div K_p = .0666222$
Weight 1 cu. ft. gas$= \dfrac{1}{32.66} = .030618$

Weight 1 cu. ft. air $= \dfrac{1}{12.387} = .080729$
8 vols. air $= 8 \times .080729 = .6456$
1 vol. gas $= 1 \times .030618 = .0306$
.6762
Proportions of mixture by weight:

Air $= \dfrac{6456}{6762} = .955$

Gas $= \dfrac{0306}{6762} = .045$ 1.000

Heating Power 1 cu. ft. gas $= 20646 \div 32.66 = 632.15$ B. T. U.
Heating Power 1 cu. ft. mixture$= 632.15 \div 9 = 70.238$ B. T. U. $= 54223.7$ ft. lbs.

THE SIBLEY JOURNAL OF ENGINEERING.

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TERMS.

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THE SIBLEY JOURNAL OF ENGINEERING,

Box 1501, Ithaca, N. Y.

THE old straight line engine, now in a dismantled condition in one of the rooms in the Mechanical Laboratory, is of considerable historical interest. It was built by students under the personal supervision of Professor John E. Sweet when at the head of the shops in Sibley College, and was the third or fourth one in number of this class of celebrated engines.

The engine itself has an excellent record, having been used to drive the shops for a long time, then used for an experimental engine in the laboratory. While Professor A. W. Smith was in charge certain changes were made in the governing apparatus, and finally the old governor was removed and one designed by

Bowen and Mount, class of '90, substituted. This substitution did not prove a success, and very little use could be made of the engine. Another engine is now needed badly to relieve the crowded condition in the department of the Mechanical laboratory. It is proposed to put this engine, in every respect, in first class condition and as near its original form as possible. Professor Sweet has been consulted, and advises certain changes in the governor, which will be made, otherwise it will be as originally built. It is believed that the engine under such circumstances will be kept in excellent order and will remain for years a monument of the good designs of Professor Sweet and of the excellent work turned out by the Sibley shops in early times.

NOTWITHSTANDING the difficulty of making a success of a student society which shall be devoted entirely to work in some special line, Cornell can boast of several which lay just claims to being, not only successful and prosperous, but of great profit to their members. The Mathematical Club, the National History Society, the History and Political Science Association, and others, all may be numbered under this head. The objection to such a society is that a student generally has so many demands upon his time that he has none left for extras, and the chief difficulty in forming and maintaining such an organization consists in creating an active interest in the work demanded from each member. If this can be done the success of the organization is assured. When the work of the society is along the line of the specialties of the members then the above objection carries no weight, for it is much over-balanced by the great advantages to be derived, not only in the information gathered from the papers presented by others, but in the almost invaluable practice obtained by preparing and delivering discussions before the society.

Although nearly every other department in the University is represented by what may be termed a "scientific student society," Sibley College so far has had no successful association of this character. Consequently, it is with pleasure that we hail the advent of what promises to be a profitable organization. The Electrical Society of Cornell University has been established for the purpose of promoting "the Electrical Arts and Sciences, and for mutual advantage to members." It will undoubtedly prove a success, and will fulfill its aims as set forth above.

GEORGE PEASE WITHERBEE.

The death of Mr. George P. Witherbee, (Cornell '93) by drowning near his home, Port Henry, on Lake Champlain, during the Summer vacation, has been known to his college-mates since their return to the University, and to his class-mates generally only recently; while it is probable that many will not have learned of this sad tragedy until seeing this notice in the college organ. The news will shock and grieve not only his old personal friends, but a large number, probably the majority of his former conrades, even though not personal acquaintances; for his lovely character and prominent position made him well-known and an interesting personality to the whole membership of the University, Faculty as well as students.

With several comrades, Mr. Witherbee started on the morning of August 28, last, on an excursion on Lake Champain, in the yacht "Alpha," the wind blowing a half-gale and the waves rising. Attempting to return when off Elm Point, a few miles from Port Henry, the jibing of the main-sail in the heavy wind upset the little craft and all were drowned with the exception of the youngest of the party, a boy of 12. Mr. Witherbee lost his life in the attempt to bring to shore one of the younger members of the party, who could not swim. He was himself an excellent and powerful swimmer and it is supposed that a cramp or other accident must have disabled him. Otherwise his death would seem almost even more inexplicable than the capsizing of a stanch boat like the "Alpha" in such skillful and competent hands.

Mr. Witherbee was born at Mineville, N. Y., July 16th, 1871, the son of Mr. Thomas P. Witherbee, the well-known iron-master of Port Henry, the inventor of the various devices now known by his name, and ex-president of the American Institute of Mining Engineers. The boy grew up in Port Henry and received his education preparatory to entering Cornell University at the Union School and Academy and, in 1888—9, at Cascadilla School at Ithaca, finally entering the University and Sibley College with the Class of '93. The writer of his obituary says;

"Always robust and healthy, he was very fond of out-door sports and during his College Course he developed a fine physique and became a great athlete, so that he held most prominent positions in the foot ball team, and the 'Varsity Crew.

"He was not only a faithful and successful student, but was also welcomed as a most desirable addition to every social meeting.

His great manly beauty was not more attractive than his finely courteous manner and always cheerful spirits.

"Never did his grand unselfishness shine forth more brightly than when at the moment of the disaster he called out, 'Which of you cannot swim,' and immediately sacrificed his wonderful strength in attempting to save the ouly helpless one instead of going to shore alone, as he could so easily have done, for he was an excellent swimmer. 'He Died for Others,' is his most appropriate epitaph."

BOOK NOTICE.

A translation of the famous work of Dr. Reauleaux by Mr. H. H. Suplee, of Philadelphia, is announced, a well-known member of the American Society of Mechanical Engineers, and a graduate of the Department of Engineers, of the University of Pennsylvania. The work is considered, by many authorities, the most complete, and in many respects, best, work on construction and machine-design in existence ; but it is criticised as being less well-adapted to American practice than Continental, and, in this respect less valuable than it would have been had it presented the forms and proportions of parts famílliar to our own mechanics and engineers.

Dr. Reauleaux says of the translation and of the translator:–

"I take this opportunity to express my particular appreciation of the great care and extraordinary accuracy which he has displayed in the production of this English version, and also my gratification at the care which has been given to the printing and the reproduction of illustrations. Mr. Suplee has recalculated and transformed all the formulæ and numerous tables into the English system of measurements, and also reworked all the examples, and has shown in this portion of the work a patience which deserves special recognition. I can only add that it is my earnest desire that the friendly acceptance of my book by English-speaking engineers may correspond to the magnitude of the labor which has been expended in the preparation of this translation."

REPORT OF INSPECTOR-GENERAL OF STEAMBOATS.

The Annual Report of the Supervising Inspector-General of Steamboats is published by the Treasury department. It is an odd arrangement by which the duty of supervision of the

merchant marine, and especially of the engines and boilers of steamboats and steamships, is confided to the Treasury Department, instead of the Navy department where it properly belongs. The Navy department has a large corps of well-educated, professionally trained engineer-officers, who could perform the duties required of them, in this direction, with intelligence and safety, and is provided with facility for the promotion of that work. The Treasury Department is compelled to organize a special corps for the work; and its construction has, in earlier times, certainly, been largely affected by politics of the lower sort. It is in consequence of this fact, probably, that we only now find in this report a recommendation for the abolition of the old form of test-piece used in the inspection of steam-boilers, with its illusive results, and the adoption of the long-standard form, among engineers, having a straight middle body, and giving intelligible and ample information in regard to the quality of the metal. The inspection-laws have been, in the main, the out-come of the recommendation of politically-appointed boards of inspectors, and have contained many absurdities, which are gradually becoming weeded out as modern methods and recent scientific advances become recognized by the better material of the later boards. We notice that the limit of tenacity permitted for boiler-steel is 65,000 pounds per square-inch, and for iron, 55,000 pounds.

CRANK SHAFTS.

—The deepest bore hole in the world is in Upper Silesia, Germany. The depth is more than 2,000 meters. The object of the boring is for thermo-metric observations.

—The Auer incandescent gas lamp, famous for its steady and brilliant light with small gas consumption, and slight development of that, is rapidly coming into use in Berlin where there are already 100,000 burners.

—The first woman in the world to obtain the degree of electrical engineer, is Miss Bertha Lamme, who graduated last June from the Ohio State University, and is now employed by the Westinghouse Company at Pittsburgh.

—The copper plating of hulls of vessels electrically is now a practical possibility, and affords all the protection of the ordinary riveted plates. The method employed is described in an article in the *Electrical Engineer* of November 1.

—The Paris Academy of Sciences have lately had exhibited to them a fire alarm apparatus termed a thermostatic balance. A hollow ball of aluminum is supported at one end of an arm, with a counterpoise at the other. Any serious change of the specific gravity of the air such as would be caused by fire, or by an excess of coal gas in it destroys the balance and the ball falls, completing an electric circuit and giving the alarm.

—The "intramural" railroad carried 6,000,000 people at the Fair last summer, without a serious accident. The great success of this road marks an epoch in the advance of electrical railroading. The adaptability of this system for rapid transit in large cities has already been appreciated, for a number of such roads have been projected, among them being one for Chicago, to connect the North Side with the down-town district.

—According to the electro magnetic theory of light, both the resistance and the transparency of a conductor should increase with its temperature; experiments yielding results conforming with this theory have been recently performed. Transparent films of metallic platinum were deposited upon glass and were heated in especially designed ovens, so arranged that light could be passed through the films and its transparency measured for various temperatures. The transparency was found to increase with the temperature; that the resistance of a conductor increases with its temperature is well known.

PERSONALS.

'91.

W. E. Lindsay now holds a position as an electrician for Swift & Co. St Louis, Mo.

'92.

R. S. Warner represents the business department of the Westinghouse Electric Co. in Washington and Oregon. He has recently married Miss Ann Pearson, Cornell, '92.

I. W. Travell, P.G., holds an excellent position with the Western Electric Co. Chicago, Ill.

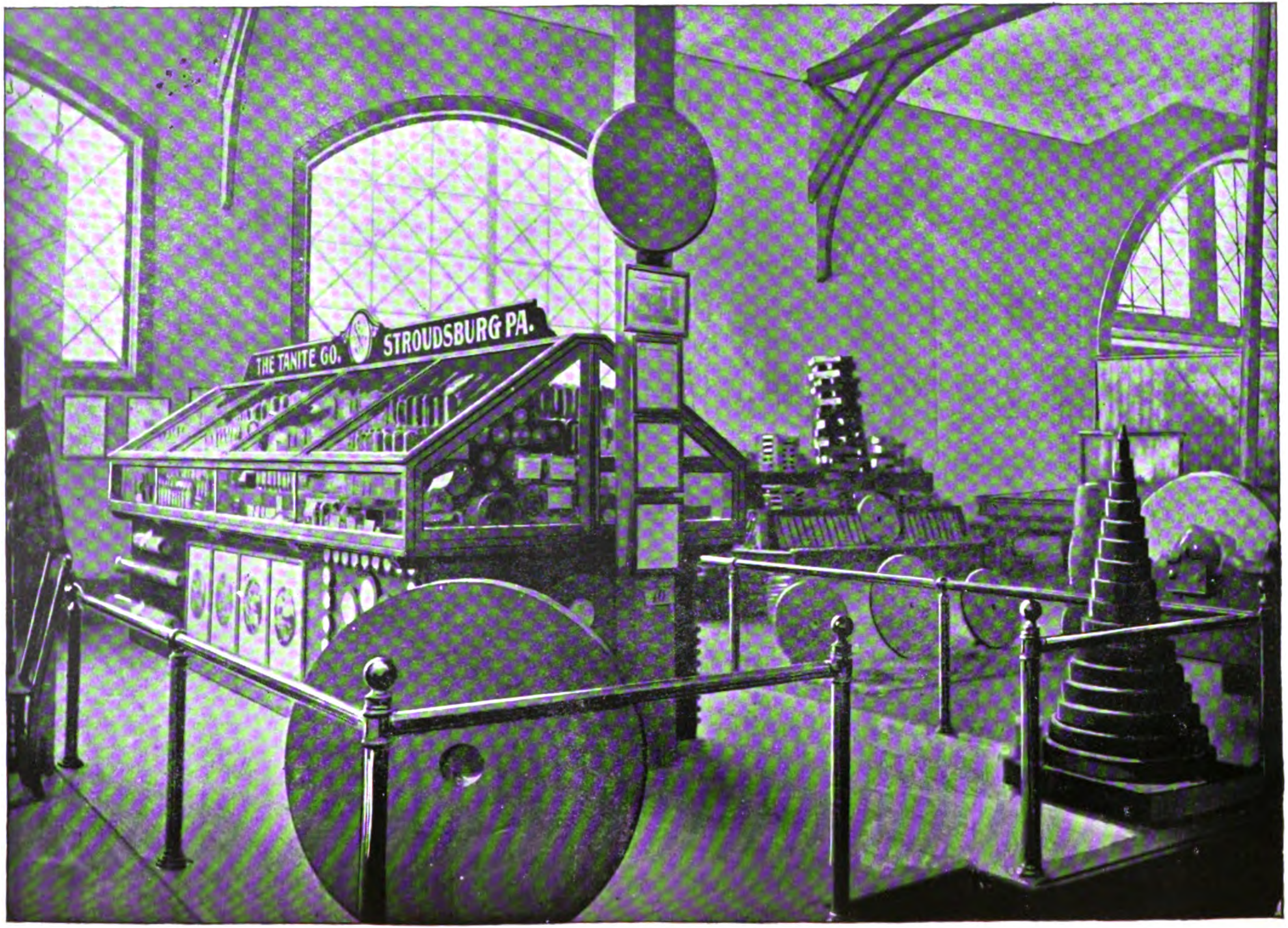
George Wardlaw is the Assistant superintendent of the Oswego Electric Power Co., of Oswego, N. Y.

J. G. Brown is imployed with McEwen & Co., Ridgeway, Pa.

'93.

W. W. Gibson holds the position of secretary of the New Jersey Art-metal Co., Passaic, N. Y.

F. J. T. Stewart holds a good position with the Westinghouse E. M. Co. of Pittsburgh.



EDUCATIONAL EXHIBIT OF ABRASIVES.

THE SIBLEY JOURNAL OF ENGINEERING.

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IN CORNELL UNIVERSITY

"The leading object shall be, without excluding other scientific and classical studies, and including military tactics, to teach such branches of learning as are related to Agriculture and the Mechanic Arts, in such manner as the legislatures of the States may respectively prescribe, in order to promote the liberal and practical education of Industrial Classes in the several pursuits and professions in life."—[An act donating public lands to the several States and Territories which may provide Colleges for the benefit of Agriculture and the Mechanic Arts, July 6, 1862.]

THE MATHEMATICAL TREATMENT OF CONTINUOUS FUNCTIONS BY APPROXIMATE METHODS.

BY W. F. DURAND.

The algebraic form of the functions herein considered is supposed to be unknown. Such functions are continually presenting themselves in engineering investigation. The data is usually in the form of a series of numerical values of one function, in terms of the regularly varying numerical values of another. Calling these functions respectively u and x, we may say that u is a function of x, although the algebraic form of such function may be entirely unknown. It is evident that if corresponding pairs of values be used for the plotting of a series of points in either rectangular or polar coördinates, a fair curve passed through such points will give approximately the geometrical form of the function between the limits concerned. Occasionally the data presents itself directly as a curve or line showing the simultaneous relation between values of x and u, and occasionally the function to be treated is related to such geometric function by means of some intermediate function whose algebraic or mathematical form is known.

As instances of functions presenting themselves in the first form, mention may be made of (1) The amount of discharge through an orifice under a determinately varying head or pressure.

(2) The intensity of magnetization in an iron bar under a determinately varying magnetizing force. (3) The resistance of a ship at determinately varying speeds.

As instances of the second form we may have (1) The contour of a section of a cut or fill. (2) The contour of an indicator card or other automatically traced diagram.

As instances of the third form, we may wish to find the statical or inertia moment of such an area, in which case the function to be integrated will be an algebraic function of the coordinates of points on the diagram.

We have purposely commenced with u as a function of one determinate variable x. We may more generally consider the variable u as a function of two determinate variables x and y (this being sufficient for most engineering purposes). In such case the geometric form of the function becomes a surface, any section of which, parallel to $X\ U$, will give u as a function of x only, for the particular value of y at which the section is taken.

As instances of such functions we may have the surface of a cut or fill, or the surface of a ship.

In such cases, however, the treatment by approximate methods is necessarily through the successive sections, or through the values of u corresponding to such sections. It will be sufficient, therefore, if we limit, for the present, our inquiry to functions of one determinate variable only.

In all cases the operations will be either geometric, algebraic, or a combination of the two.

The mathematical treatment of such functions usually involves either (1) Integration, (2) Differentiation, or (3) Interpolation.

We shall here consider algebraic operations only, and we shall find it convenient to begin with interpolation.

Suppose that we have given a series of values of the function u corresponding to values of x separated by the finite increment h. Denoting these by u_0, u_1, u_2, etc., we have the first column in the table below. Taking the successive columns of differences we readily find the columns headed Δ_1, Δ_2 and Δ_3. The law of co-

	Δ_1	Δ_2	Δ_3
u_0			
u_1	$u_1 - u_0$		
u_2	$u_2 - u_1$	$u_2 - 2\ u_1 + u_0$	
u_3	$u_3 - u_2$	$u_3 - 2\ u_2 + u_1$	$u_3 - 3\ u_2 + 3\ u_1 - u_0$
u_4	$u_4 - u_3$	$u_4 - 2\ u_3 + u_2$	$u_4 - 3\ u_3 + 3\ u_2 - u_1$

efficients and signs is obvious and may be easily generalized by the reader. Calling the first member of each column Δ_{10}, Δ_{20}, Δ_{30}, etc., we have the following :

$$u_0 = u_0. \qquad (1)$$

$$\Delta_{10} = u_1 - u_0. \qquad (2)$$

$$\Delta_{20} = u_2 - 2\,u_1 + u_0. \qquad (3)$$

$$\Delta_{30} = u_3 - 3\,u_2 + 3\,u_1 - u_0. \qquad (4)$$

From (2) we have :

$$u_1 = u_0 + \Delta_{10}. \qquad (5)$$

From (3) and (5) we have :

$$u_2 = u_0 + 2\,\Delta_{10} + \Delta_{20}. \qquad (6)$$

And from (4), (5) and (6) :

$$u_3 = u_0 + 3\,\Delta_{10} + 3\,\Delta_{20} + \Delta_{30}. \qquad (7)$$

The law of coefficients and subscripts is easily seen and we may readily write the generalized form as follows :

$$u_x = u_0 + x\,\Delta_{10} + x\frac{(x-1)}{2}\,\Delta_{20} + x\frac{(x-1)(x-2)}{3\,!}\,\Delta_{30} + \ldots \qquad (7)$$

This is a general formula of interpolation, giving, as it does, the value of any member of the series u_x in terms of the initial member u_0, and the initial members of the successive series of differences.

Now while the form of the function u is not supposed to be known, it is supposed to be such that for short distances it may be closely approximated to by an algebraic function. For an algebraic function of the nth degree the order of difference Δ_{n+1} will become 0 and therefore $\Delta_{(n+1)0}$ will be 0. The omission in (7) of all terms after the one involving Δ_{n0} is therefore equivalent to stopping the approximation at that point, and to considering that the function u between the limits 0 and xh is represented by an algebraic function of the nth degree.

If $n = 1$ the approximation is linear, and we have :

$$u_x = u_0 + x\,\Delta_{10} = u_0 + x\,(u_1 - u_0) = -\,(x-1)\,u_0 + x\,u_1. \qquad (8)$$

This is the usual formula for linear interpolation in which, if values of x intermediate between 0 and 1 are substituted, the corresponding values of u will be given.

If $n = 2$ the approximation is equivalent to the substitution of a second degree parabola for the actual contour between the limits in question. Omitting all after the second term and reducing by the aid of (1), (2), and (3), we have :

$$u_x = u_0 + x\Delta_{10} + \frac{x(x-1)}{2}\Delta_{20} = \frac{(x-1)(x-2)}{2}u_0 - x(x-2)u_1 + x\frac{(x-1)}{2}u_2. \qquad (9)$$

Similarly if $n = 3$ the substituted contour is a third degree parabola. Reducing as before, we find :

$$u_x = \frac{-(x-1)(x-2)(x-3)}{6}u_0 + \frac{x(x-2)x-3)}{2} - u_1 - \frac{x(x-1)(x-3)}{2}u_2 + \frac{x(x-1)(x-2)}{6}u_3. \qquad (10)$$

This may be easily generalized, and we may see that if the parobola is taken of the nth degree there will be $(n+1)$ terms in u_x of which the term u_p may be written in the form :

$$\frac{x(x-1)(x\quad 2) - - - - (x-n)(p-p)}{p(p-1)(p-2) - - - - (p-n)(x-p)}u_p. \qquad (11)$$

For all ordinary engineering purposes the second degree parabola is considered as a sufficiently close approximation, and values of x between 0 and 2 substituted in (9) will give the corresponding values of u. Values in general outside the limits 0 and n may, of course, be put for x; but in such case the operation is one of extrapolation, and must be applied with caution.

The cases most commonly met with are those in which the interval h is to be subdivided into two or ten equal parts. The former is contained in the latter, for which we have the following formulas :

$$\begin{aligned}
u_0 &= u_0 \\
u_{.1} &= .855\,u_0 + .19\,u_1 - .045\,u_2 \\
u_{.2} &= .72\,u_0 + .36\,u_1 - .08\,u_2 \\
u_{.3} &= .595\,u_0 + .51\,u_1 - .105\,u_2 \\
u_{.4} &= .48\,u_0 + .64\,u_1 - .12\,u_2 \\
u_{.5} &= .375\,u_0 + .75\,u_1 - .125\,u_2 \\
u_{.6} &= .28\,u_0 + .84\,u_1 - .12\,u_2 \\
u_{.7} &= .195\,u_0 + .91\,u_1 - .105\,u_2 \\
u_{.8} &= .12\,u_0 + .96\,u_1 - .08\,u_2 \\
u_{.9} &= .055\,u_0 + .99\,u_1 - .045\,u_2 \\
u_1 &= u_1
\end{aligned}$$

The values of terms between u_1 and u_2 may be readily written symmetrically with the above.

It is, of course, understood that $u_0\ u_1\ u_2$ may represent *any* three consecutive ordinates or values of u, separated by the common interval h; or more generally, that $u_0\ u_1\ u_2 \ldots\ldots$ may represent any consecutive series of values of u separated by the same interval.

We will next consider the operation of integration. The actual value of any abscissa, it will be remembered, is $h\,x$, where x denotes the value as used above in terms of the unit h. The differential of such value is therefore $h\,dx$. Taking, therefore, the value of u_x in (7), we wish to effect the integration $\int u_x\, h\, dx$ between limits for x of o and some value a. Performing the integrations we have:

$$
\begin{aligned}
h\int_0^a u_x\,dx = {} & hau_0 + h\frac{a^2}{2}\triangle_{10} + h\left(\frac{a^3}{3} - \frac{a^2}{2}\right)\frac{\triangle_{20}}{2} + h\left(\frac{a^4}{4} - a^3 + a^2\right)\frac{\triangle_{30}}{3\,!} \\
& + h\left(\frac{a^5}{5} - \frac{3a^4}{2} + \frac{11}{3}a^3 - 3a^2\right)\frac{\triangle_{40}}{4\,!} \\
& + h\left(\frac{a^6}{6} - 2a^5 + \frac{35}{4}a^4 - \frac{50}{3}a^3 + 12a^2\right)\frac{\triangle_{50}}{5\,!} \\
& + h\left(\frac{a^7}{7} - \frac{15}{6}a^6 + 17a^5 - \frac{275}{4}a^4 + \frac{274}{3}a^3 - 60\,a^2\right)\frac{\triangle_{60}}{6\,!} \qquad (12)
\end{aligned}
$$

In (12) it is evident that the value of the integral as an approximation will increase in accuracy with the number of terms included, and therefore that the residual error will grow less in the same way. In practice it is found more convenient to express the values of $\triangle_{10}$, $\triangle_{20}$, etc., in terms of the successive values of u. This is effected by means of (2), (3), (4), etc. The value of the integral is thus expressed in terms of the successive values of the function given by values of x between o and a inclusive. Reference to (3) or (4) shows that in order to find $\triangle_{n0}$, all values of u must be known from u_0 to u_n inclusive.

In the way these formulas are ordinarily used, it is usually not convenient to have the integral between o and a inclusive involve values of u outside of the range u_0 to u_a. It follows, therefore, that if values beyond u_a are not to be included, differences beyond $\triangle_{a0}$ are also excluded, and the approximation will stop at that point. It will be noted that this is an arbitrary and not a neces-

sary restriction. It is perfectly possible, for example, to derive a value of $h\int_1^2 u_x\,dx$ involving differences to any desired order, and therefore involving any desired number of functions of u. Considerations of convenience, however, usually require the restriction referred to. On this understanding we will substitute values for a in (12).

Let $a = 1$ and we have $\int_0^1 = h(u_0 + \frac{1}{2}\Delta_{10})$. But from (2) we have $\Delta_{10} = u_1 - u_0$.

Substituting and reducing we have:

$$\int_0^1 = \frac{h}{2}\Big(u_0 + u_1\Big) \tag{13}$$

In a similar way let $n = 2$ and we find:

$$\int_0^2 = \frac{h}{3}\Big(u_0 + 4u_1 + u_2\Big) \tag{14}$$

Proceeding in a similar way with other values of n, we find:

$$\int_0^3 = \frac{3h}{8}\Big(u_0 + 3u_1 + 3u_2 + u_3\Big) \tag{15}$$

$$\int_0^4 = \frac{2h}{45}\Big(7(u_0 + u_4) + 32(u_1 + u_3) + 12u_2\Big) \tag{16}$$

$$\int_0^5 = \frac{5h}{288}\Big(19(u_0 + u_5) + 75(u_1 + u_4) + 50(u_2 + u_3)\Big) \tag{17}$$

For $\int_0^6$ we find as the coefficient of Δ_{60} the value $\frac{41}{140}$. Taking instead $\frac{40}{140}$ or $\frac{2}{7}$, we find:

$$\int_0^6 = \frac{3h}{10}\Big(u_0 + u_2 + u_4 + u_6 + 5(u_1 + u_5) + 6u_3\Big) \tag{18}$$

As an exception to the general rule that it is not convenient to include values of u beyond the range u_0 to u_n, we find it sometimes of use to be able to express $\int_0^1$ in terms of u_0 u_1 and u_2, and $\int_1^2$ in terms of u_0 u_1 u_2 u_3. To this end let $a = 1$ in (12) and include Δ_{20}.

We thus derive in the usual way:

$$\int_0^1 = \frac{h}{12}\Big(5u_0 + 8u_1 - u_2\Big) \tag{19}$$

Again, let the limits be 1 and 2 in (12) and include Δ_{30}. Reduce as before and we find:

$$\int_1^2 = \frac{h}{24}\Big(13(u_1 + u_2) - (u_0 + u_3)\Big) \tag{20}$$

It will be seen that these various rules are exact if the $(a+1)$st column of differences vanishes. That is, (14) is exact if the third order of differences becomes o, and similarly for the others. Again, we know in general that if u is algebraic and of the nth degree in x, the $(n+1)$st derivitive is o. It follows that any given rule is exact if u is algebraic and of a degree a or less. Therefore (13) is exact if u is linear, and is, in fact, the ordinary trapezoidal rule. Likewise, (14) is exact for a quadratic function, (15) for a cubic, etc.

We wish next to show that when a is even, the rule is exact for a function of the $(a+1)$st degree. This will result if the term involving $\Delta_{(a+1)0}$ becomes o. Now, the coefficient of $\Delta_{(a+1)0}$ is

$$P = \frac{1}{(a+1)!}\int_0^a x(x-1)(x-2)\cdots\cdots(x-a)dx.$$

Let $x = n - y$. Then $dx = -dy$ and :

$$P = \frac{1}{(a+1)!}\int_a^0 (a-y)(a-1-y)(a-2-y)\cdots(1-y)(-y)(-dy).$$

The terms of the two integrals are the same in the inverse order and with the opposite sign. But since a is even, the number of terms is even. The two expressions under the $\int$ are, therefore, equal. But the limits are interchanged. Hence we have $P = -P$ or $P = O$.

The rules given in (13) and (14) are Simpson's one-third and three-eighth rules. For functions not higher in degree than the third, they are exact, and therefore equally correct. The rule given in (17 is called Weddel's, but though relatively simple in form, it is rarely used.

For engineering purposes rules (13), (14), (15) and (19) have filled all practical requirements. The rules given in (16), (17) and (18) have been deduced as illustrative examples of the generality of the method of deduction.

A single application of any one of these rules will give the value of the integral for a intervals. For integration between extended limits, the total interval must be divided into an exact number of parts, each one of which must contain a smaller intervals h. The rule is then applied to each of these and the results

summed. In this way we derive from (13), omitting the successive u_s and writing simply the coefficients :

$$A = h\left(\tfrac{1}{2} + 1 + 1 + 1 \text{ - - - - - - } \tfrac{1}{2}\right). \qquad (20)$$

Similarly from (14) and (15) :

$$A = \frac{h}{3}(1 + 4 + 2 + 4 + 2 \text{ - - - - } 1). \qquad (21)$$

$$A = \frac{3}{8}h(1 + 3 + 3 + 2 + 3 + 3 + 2 + \text{ - - - - } 1.) \qquad (22)$$

Rule (20) is applicable to any number of intervals or ordinates. Rule (21) is applicable only when the number of intervals is even or of ordinates odd. Rule (22) is applicable only when the number of intervals is a multiple of three. There are certain numbers of intervals, such as 5, 7, 11, etc., to which neither (21) nor (22) will apply, and for which a combination of the two, or some other rule or combination must be used. The advantages of (20) over (21) or (22) in point of simplicity and generality of application are very great. The disadvantage lies in its inferior accuracy. In general it will be found that about double the total number of intervals will be required for equal accuracy with (20) as compared with (21) or (22).

We shall now proceed to derive certain new rules which will give substantially the simplicity of application of the trapezoidal rule, while retaining the accuracy of the parabolic rules.

Writing (21) for eight intervals we have the first line as follows :

$$\begin{array}{rlllllllll}
A = h(& \frac{1}{3} & \frac{4}{3} & \frac{2}{3} & \frac{4}{3} & \frac{2}{3} & \frac{4}{3} & \frac{2}{3} & \frac{4}{3} & \frac{1}{3}). \\
h(& & \frac{1}{3} & \frac{4}{3} & \frac{2}{3} & \frac{4}{3} & \frac{2}{3} & \frac{4}{3} & \frac{1}{3} &). \\
h(& \frac{5}{12} & \frac{2}{3} & -\frac{1}{12} & & & & -\frac{1}{12} & \frac{2}{3} & \frac{5}{12}). \\
\hline
A = h(& \frac{3}{8} & \frac{7}{6} & \frac{23}{24} & 1 & 1 & 1 & \frac{23}{24} & \frac{7}{6} & \frac{3}{8}).
\end{array} \qquad (23.$$

Applying the same rule to the six mean intervals we have the second line. Applying (19) to the end intervals we have the third line. We have thus written the same integral twice. Taking half the sum we find the fourth line.

This has been derived from an even number of sections. Writing rule (21) for the first six and for the last six of seven intervals, we have the upper two lines as follows :

$$\begin{array}{rlllllllll}
 & h(\tfrac{1}{3} & \tfrac{4}{3} & \tfrac{2}{3} & \tfrac{4}{3} & \tfrac{2}{3} & \tfrac{4}{3} & \tfrac{1}{3} & &). \\
 & h(& \tfrac{1}{3} & \tfrac{4}{3} & \tfrac{2}{3} & \tfrac{4}{3} & \tfrac{2}{3} & \tfrac{4}{3} & \tfrac{1}{3} &). \\
 & h(\tfrac{5}{12} & \tfrac{2}{3} & -\tfrac{1}{12} & & & -\tfrac{1}{12} & \tfrac{2}{3} & \tfrac{5}{12} &). \\
\hline
A = & h(\tfrac{3}{8} & \tfrac{7}{6} & \tfrac{23}{24} & 1 & 1 & \tfrac{23}{24} & \tfrac{7}{6} & \tfrac{3}{8} &).
\end{array} \qquad (23)$$

Applying (19) to the end intervals and summing, we reach a similar result but for an odd number of intervals.

It thus appears that (23) is applicable to either an odd or an even number of intervals.

For greater ease of application this rule may be written:

$$A = h\left(\begin{array}{cccccccc} 1 & 1 & 1 & 1 \text{ - - - - - } 1 & 1 & 1 & 1 \\ -\tfrac{5}{8} & +\tfrac{1}{6} & -\tfrac{1}{24} & & -\tfrac{1}{24} & +\tfrac{1}{6} & -\tfrac{5}{8} \end{array}\right) \qquad (24)$$

In accordance with this form the ordinates are first summed as though all coefficients were 1. We then add $\frac{1}{6}$ the sum of the second from each end, and subtract $\frac{5}{8}$ the sum of the end ordinates plus $\frac{1}{24}$ the sum of the third from each end. Relatively, in such a rule, the advantage increases with the number of intervals.

In deriving (23) if we use (13) instead of (19) for the end intervals we shall derive a rule as follows:

$$A = h(\tfrac{5}{12} \quad 1\tfrac{1}{12} \quad 1 \quad 1 \text{ - - - - - } 1 \quad 1 \quad 1\tfrac{1}{12} \quad \tfrac{5}{12}). \qquad (25)$$

Or

$$A = h\left(\begin{array}{cccccc} 1 & 1 & 1 & 1 \text{ - - - - - } 1 & 1 & 1 & 1 \\ -\tfrac{7}{12} & +\tfrac{1}{12} & & & +\tfrac{1}{12} & -\tfrac{7}{12} \end{array}\right) \qquad (26)$$

The application of (26) is somewhat simpler than that of (24) and the loss in accuracy practically negligible. If instead of $\frac{5}{12}$ and $1\frac{1}{12}$ in (25) we write .4 and 1.1, the difference will be but slight, and the rule so modified will usually give a result lying between those given by (24) and (26). Writing the rule thus modified we have:

$$A = h(\ .4 \quad 1.1 \quad 1 \quad 1 \text{ - - - - - } 1 \quad 1 \quad 1.1 \quad .4). \qquad (27)$$

Or

$$A = h\left(\begin{array}{cccccc} 1 & 1 & 1 & 1 \text{ - - - - - } 1 & 1 & 1 & 1 \\ -.6 & +.1 & & & +.1 & -.6 \end{array}\right) \qquad (28)$$

In this form the application of the rule is as general and practically as simple as that of the trapezoidal, while the accuracy is

substantially the same as that of (24) or (26) and will usually be found between the two.

In comparing the accuracy of (24), (26) and (28) with that of (21) it should be noted that the latter is based upon the substitution for the true but perhaps unknown contour, of a simple series of parabolic arcs. The former are based upon the substitution of a double series of parabolic arcs, and is the mean of such double application. Now there is no reason *a priori* why the substituted arcs should begin at one point rather than at another, and it seems only reasonable to assume a somewhat increased accuracy for the mean of a pair of results, either of which is equally probable, over either of these results singly.

The question is really one of probability, for the contours in question are not algebraic, and it becomes a question of the degree of probability with which a single, or the mean of a double, series of parabolic arcs may be expected to accurately replace the true contour.

In a series of cases taken at hazard, the difference in the results obtained by rules (24) and (28) varied from one part in thirty thousand to one part in seventy thousand. It would thus seem fair to claim for (28) substantially the full probable accuracy of (21) with the ease and generality of application of (20).

In connection with the subject of approximate integration it may be noted that these rules and methods are applicable to integrals of any and every form, and not merely to areas as is sometimes implied. They are essentially methods of approximate *integration*, and not merely methods of approximate *quadrature*. Any integral with reference to a variable x may be put in the form $\int u\,dx$, and if individual values of u can be found, the value of the integral may be approximately computed.

In closing this section it may be noted that when the integration is with reference to an angle θ, the value of the interval $\Delta\,\theta$ must be taken in angular measure.

We may next note briefly the operation of approximate differentiation. Here as in integration we must remember that the true value of an abscissa corresponding to x is $x\,h$, and that the differential coefficient desired is therefore

$$\frac{d\,u_x}{d\,(h\,x)} = \frac{1}{h}\frac{d\,u_x}{d\,x}.$$

Performing the operations we have from (7) :

$$\frac{1}{h}\frac{d\,u_x}{d\,x} = \frac{1}{h}\left[\Delta_{10} + (x - \tfrac{1}{2})\,\Delta_{20} + \left(\frac{x^2}{2} - x + \tfrac{1}{3}\right)\Delta_{30} + \cdot\cdot\right] \quad (29)$$

With linear approximation we have :

$$\frac{1}{h}\frac{du_x}{dx} = \frac{\Delta_{10}}{h} = \frac{u_1 - u_0}{h}. \quad (30)$$

Including Δ_{20} and reducing we have :

$$\frac{d\,u_x}{h\,d\,x} = \frac{1}{h}\left[u_0\,(x - \tfrac{3}{2}) - u_1(2\,x - 2) + u_2\,(x - \tfrac{1}{2})\right] \quad (31)$$

If in this we put $x = 1$ we find :

$$\frac{d\,u_x}{h\,d\,x} = \frac{u_2 - u_0}{2\,h}. \quad (32)$$

This gives the tangent of the inclination ϕ of the approximate contour, to the axis of x, at a point midway between two ordinates u_0 and u_2.

If in (31) we put $x = 0$ we find :

$$\text{Tan}\ \phi = \frac{4\,u_1 - u_2 - 3\,u_0}{2\,h}. \quad (33)$$

Similarly for $x = 2$:

$$\text{Tan}\ \phi = \frac{u_0 + 3\,u_2 - 4\,u_1}{2\,h}. \quad (34)$$

This gives tan ϕ at the end of a parabolic arc in terms of the three ordinates u_0, u_1, u_2.

For any other point, of course, the proper value will be given by the substitution of the appropriate value of x.

For tan ϕ at the middle one of five ordinates, we may take the mean of the two values found by taking the two sets of three ordinates $u_0\ u_1\ u_2$, and $u_2\ u_3\ u_4$. From (33) and (34) we find the value derived in this way to be :

$$\tan \phi = \frac{3(u_4 - u_0) - 4(u_3 - u_1)}{4h} \tag{35}$$

Similar expressions for tan ϕ may be found from the third degree parabola by retaining Δ_{30}, but for most purposes, those derived from the second degree parabola, as above, will be sufficiently accurate.

As another operation closely related to differentiation, we may consider the method of locating a maximum or minimum value of u. To this end we have simply to put tan $\phi = 0$ and solve for x. From (31) we thus find :

$$x = \frac{2u_1 - \frac{3}{2}u_0 - \frac{1}{2}u_2}{2u_1 - u_0 - u_2} \tag{36}$$

This locates a maximum or minimum value of u_x with reference to u_0 as origin. It may be more convenient to locate the point with reference to u_1, the middle one of the three ordinates. To this end subtract 1 from the value of x above and we find :

$$x_1 = \frac{u_2 - u_0}{2(2u_1 - (u_2 + u_0))} \tag{37}$$

The general accuracy with which these methods of parabolic approximation may be used for the treatment of irregular and unknown functions depends on the size of the interval h relative to the variation in u. The value of h must be small enough so that for two or three intervals, at least, the law for u is smooth, and its variation free from multiple changes of sign. In any particular case the desired degree of accuracy and the particular characteristics of the function concerned will form a basis for a judgment as to the extent of subdivision necessary.

The whole question turns, of course, on how closely the substituted parabolic law can, for a pair of intervals (or for a intervals in general) represent the true but unknown law ; and this fact kept in view will be of considerable aid in a determination of the necessary degree of subdivision in any particular case. Especially will this be so if the geometrical form of the contour is a part of the data in hand.

ALTERNATING CURRENT MEASUREMENT BY INSTANTANEOUS CONTACT.*

BY FREDERICK BEDELL, K. B. MILLER AND G. F. WAGNER.

Of the various methods employed for the investigation and study of alternating cnrrents, none are more interesting than the experimental method whereby the instantaneous changes in the periodically varying quantities are made known. We refer to the method of instantaneous contact.

For the complete analysis of alternating current phenomena, we should know not only the value of each changing quantity at every part of its period, but we should know the phase relations between the several varying quantities; that is, the relations between their respective zero and maximum values. To enable us to do this, the method of instantaneous contact has come into use, in which a revolving contact is made at a particular part of the period in such a way that we may ascertain the value at that particular instant of any of the varying quantities measured. This method is of historical as well as scientific interest, inasmuch as it was orginially devised simultaneously on each side of the Atlantic and has since been modified and developed by many investigators.

An interesting account of the development of the method of instantanteous contact is given by Dr. Nichols in his address, as Vice-President, before the physical section of the American Association for the Advancement of Science, upon "The Phenomena of the Time-infinitesimal,"[1] and a brief review may now be in place, previous to the description of the present modification.

In the year 1880, Joubert[2] made use of the device in his study of the changes in potential of an alternating current dynamo and between the terminals of the Jablochkoff candle, and pointed out the use of the quadrant electrometer in alternating current measurement. In the same year B. F. Thomas, in this country, devised the method independently, and made use of a condenser and ballistic galvanometer. His paper before the American Association

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* From a paper entitled "Hedgehog Transformers and Condensers" presented before the American Institute of Electrical Engineers, October 18. We are indebted to the Institute for the use of cuts.

1. E. L. Nichols: *Proceedings Am. Assoc. for the Adv. of Sc.*, Madison Meeting, vol. xlii., 1893.

2. Joubert: "Sur les Courants alternatifs et la force electromotive de l'arc electrique." *Comptes Rendus*, 91, p. 161, July 19, 1880.

for the Advancement of Science[1] that year was published by title only, and his experiments were unpublished until presented, by request, at a meeting of this INSTITUTE[2] last year.

In 1888, the method was used by Duncan, Hutchinson and Wilkes,[3] who applied it to the study of induction coils and transformers, and obtained the first complete set of curves for this class of alternating current apparatus. In the same year it was used in France by Meylan,[4] in a study of the vibratory call-bell of Abdank, and at Stevens Institute, in an investigation of the Westinghouse Alternator by Searing and Hoffman.[5]

Then followed its use by various investigators, Ryan and Merritt,[6] Humphrey and Powell,[7] Tobey and Walbridge,[8] Marks,[9] Herschel,[10] Fortenbaugh and Sawyer,[11] all of whom used it in the study of alternating current phenomena and have communicated their results before this INSTITUTE. Subsequently the method has been employed for different lines of investigation by Archibald and Teeple,[12] Thompson,[13] Ryan,[14] Hopkinson,[15] and a modification has been used by Duncan[16] in which simultaneous

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1. Henry Morton and B. F. Thomas : "Observations on the Electromotive Forces of the Brush Dynamo-electric Machine." *Proceedings A. A. A. S.*, vol. xxix., p. 277, 1880.

2. B. F. Thomas : "Notes on Wiping Contact Methods for Current and Potential Measurement." TRANSACTIONS, A. I. E. E., vol. ix., p, 263, 1892.

3. Duncan, Hutchinson and Wilkes : "Experiments on Induction Coils." *Electrical World*, vol. xi., p. 160, 1888.

4. Meylan : "Sur les Apples Magnetiques." *La Lumière Électrique*, vol. xxvii, p. 220, 1888.

5. Searing and Hoffman : "Variation of the Electromotive Force in the Armature of a Westinghouse Dynamo." *Journal of the Franklin Iustitute*, vol. 123, page 93.

6. Ryan : "Transformers." TRANSACTIONS, vol. vii, p. 1, 1889.

7. Humphrey and Powell : "Efficiency of Transformers." TRANSACTIONS, vol. vii, p. 311.

8. Tobey and Walbridge : Investigation of the Stanley Alternate-current Arc Dynamo." TRANSACTIONS, vol. vii, p. 367.

9. Marks : TRANSACTIONS, vol. vii, p. 324.

10. Hercshel : TRANSACTIONS, vol. vii, p. 328.

11. Fortenbaugh and Sawyer : TRANSACTIONS, vol. vii. p. 334.

12. Nichols :" On Alternating Electric Arc between a Ball and a Point." *American Journal of Science*, vol. xli, p. 1.

13. M. E. Thompson : "Study of an Open-Coil Arc Dynamo." TRANSACTIONS, vol. viii, p. 375.

14. Ryan : "Relation of the Air Gap and the Shape of the Poles to the Performance of Dynamo-electric Machines." TRANSACTIONS, vol. viii, p. 451.

15. Hopkinson : " Dynamo Machinery and Allied Subjects, p. 187.

16. Duncan : " Note of some Experiments with Alternating Currents." TRANSACTIONS, vol. ix, p. 179.

curves are rapidly obtained by the use of several dynamometers. This is the history of the method from its first use to the writing of this paper.

The features introduced in the method as employed in the present investigation are two; first, the use of a revolving contact-maker, in which the contact is made by a needle passing through a water-jet; and, second, the use of a condenser to displace the zero of an electrostatic potential instrument, so that readings are taken at the best portion of the scale.

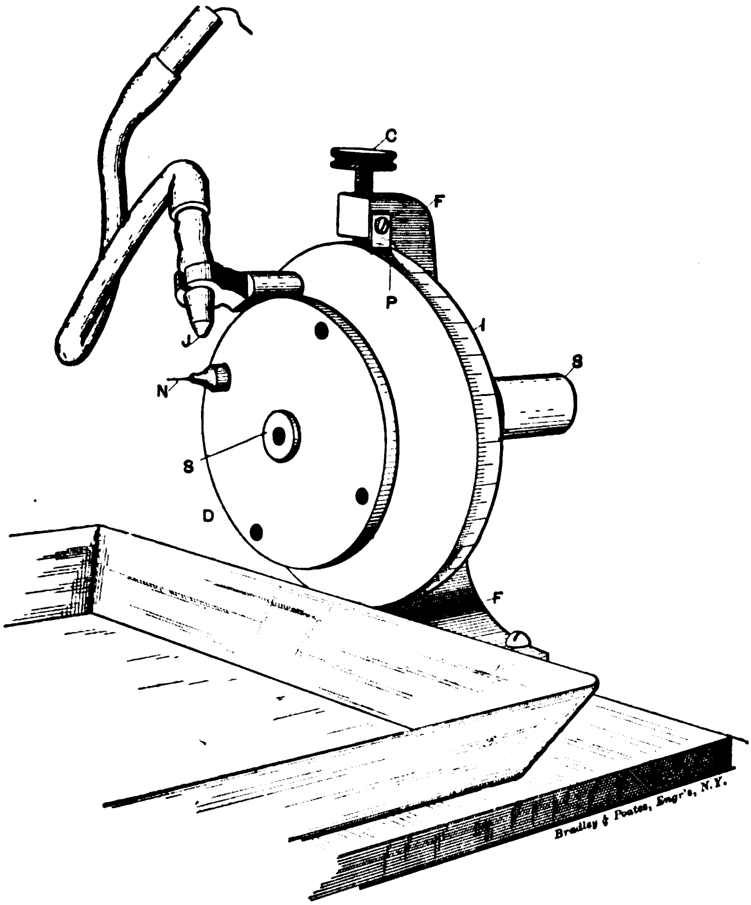


FIG. I.—*Bedell-Ryan Revolving Contact-Maker.*

A general view of the revolving contact-maker is given in Fig. 1, and a detailed view in Fig. 2. The whole instrument is sup-

ported by a stationary frame F. The shaft S is connected to the armature shaft of the dynamo by a coupling (not shown) on the end of the rod R, and carries the disk D, which revolves with it. The needle N projects from this disk and forms one of the electrodes of the contact. The other electrode is a fine water-jet (not shown) issuing from the nozzle J, well insulated by hard rubber from the rest of the instrument. This fine jet is maintained from a jar of water, several feet above, to which it is connected by a flexible rubber tube. Electrical connection is maintained with the water-jet by a wire W, which passes through this tube and is soldered to the nozzle J. Electrical connection with the needle-point electrode is obtained through the shaft and frame of the instrument. The needle cuts the water-jet once in every revolution

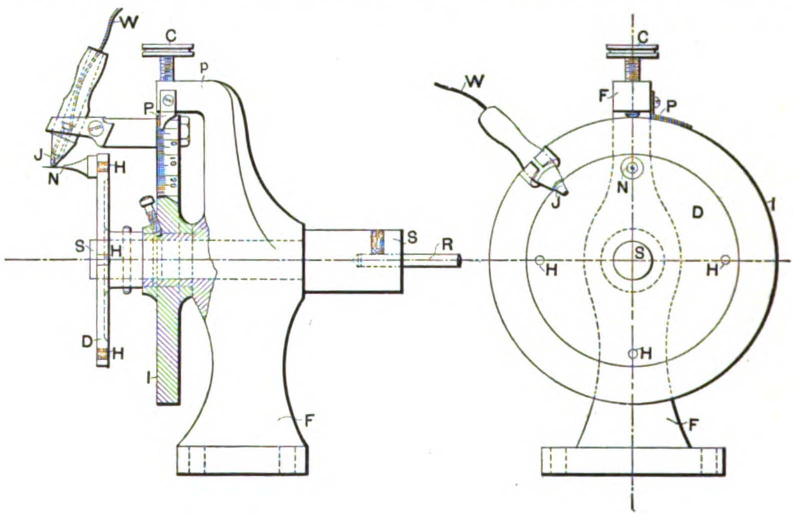


FIG. 2.

of the armature of the dynamo and makes a contact which is well defined and unvarying. The nozzle of the water-jet is carried upon an index-disk I, which can be turned into any position by revolving it upon a projecting collar of the frame, which forms its bearing. The water-jet is held in any position by securing the index-disk by means of the set-screw C in the top of the frame. Its position is indicated by the pointer P, upon the scale on the circumference of the index-disk, which is graduated in degrees.

The needle cuts the water-jet very near the nozzle, at a point where the jet is quite stiff, due to the head of water. The nozzle

is radial, and the jet keeps the direction of the nozzle for some little distance before being materially deviated by gravity. A little salt was put in the water to increase the conductivity of the jet. Pure water would not work; acidulated water corroded the nozzle thus changing the jet.

It was after working for some time with various mechanical contact-makers, that this water-jet form was devised, It came up to our expectations in every respect, the contact being perfectly constant and reliable, and free from the changes always found in a mechanical device, due to the wearing away of the contacts. This constancy is particularly necessary in an instrument which is to be used in an extended investigation, during which any change would be fatal. By maintaining a fine, strong jet, for which a head of five or six feet is ample, and using a fine needle close to the nozzle, the instrument may be used with great precision and needs but little attention, running every night for weeks with scarcely any interruption. Of course, the accuracy of the instrument is increased as the diameters of the disks are made greater.

For use in another investigation, in which it was desired to obtain measurements for several consecutive cycles, without interruption, the instrument was made so that the needle could be secured in the disk D, by screwing it into any of the four holes H, thus making it possible to have the contact made with the armature in any desired position, without moving the nozzle more than forty-five degrees from the vertical.

This contact-maker was used with a Thomson Multicellular voltmeter, as shown in Fig. 3. The difference of potential between *a* and *b* is to be measured. The condenser C_1, is kept charged to this potential to be measured, being connected through the contact-maker. The voltmeter used reads between 40 and 120 volts. Its zero was displaced by the condenser C_2, in series with it, which was kept charged to about 80 volts; that is, the voltmeter reading indicated the sum of the potentials of the two condensers C and C_2, so that a reading of 80 volts indicated that there was no difference of potential between the terminals of condenser C_1, or between *a* and *b*; a reading of 85 volts indicated 5 volts difference of potential and so on.

When a difference of potential beyond the range of the instrument was to be read, the apparatus was arranged as in Fig. 4; for instance, suppose it was desired to obtain the difference of potential between A and B. These points were connected by a non-inductive resistance, and the difference of potential was measured

around a known portion, *a*, *b*, of this resistance, and the whole difference of potential between A and B calculated.

Measurement of current was obtained by the potential instrument in a similar way. A non-inductive resistance was inserted in the circuit, in which the current was to be measured, as in Fig. 4. From the curve representing the instantaneous values of E. M. F. around these lamps, the square root of the mean sqnare value

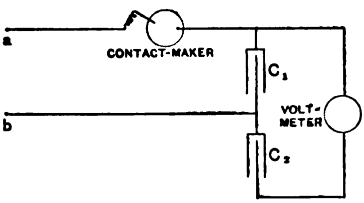


FIG. 3.

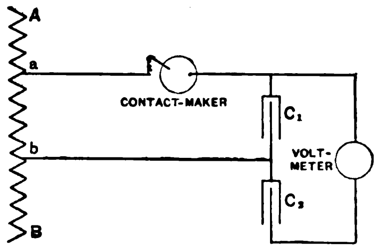


FIG. 4.

of the E. M. F. was determined. The lamps were previously calibrated by a continuous current and their resistance determined for any value of E. M. F. at their terminals. For an alternating current their resistance was ascertained from this calibration for the square root of the mean square value of the E. M. F. at their terminals and this value of their resistance was used to obtain the instantaneous values of the current from the instantaneous values of E. M. F. in accordance with Ohm's law.

The multicellular voltmeter is ordinarily a slow instrument to read. Readings were quickened by a pneumatic damping arrangement, devised by Professor Ryan, consisting of two rubber tubes, each connected at one end to the same rubber bulb, their other ends terminating in fine glass tubes leading down through the glass cover of the voltmeter. By pumping air from the bulb through one or the other of these tubes, a draught could be produced against the needle, so as to oppose its motion and bring it quickly to rest.

The apparatus described makes it possible to read current and potentials through any possible range. The method of instantaneous contact is a valuable one for investigation of alternating current phenomena and may be made accurate and precise for refined laboratory research, while at the same time it is capable of meeting the requirements of rougher practical work where convenience and durability of apparatus is paramount to extreme precision.

FRENCH ENGINEERS AND AMERICAN ENGINEERING.

At the meeting of December 8th, of the "*Societe d'Encouragement*," the distinguished author and engineer, Mon. G. Richard, gave his impressions of American Engineering, as seen at the Chicago Exposition.

After speaking of the immense tonnage of the city of Chicago, of its provisions for the storage and sale of grain, of cattle and of hogs, and of its peculiarly enormous buildings, he refers in terms of unqualified praise, to the engineering of the city and its connections. The city is supplied with some 650 kilometers of elevated and cable roads, "which are operated with perfect regularity and constitute a means of conveyance of incomparable efficiency," subject to very few accidents. For routes of comparatively small traffic, the electric roads are preferred, however, and many are in use. "The effectiveness of these mechanical and electrical tramways, the facility of their installation, and the security with which they are operated, are such that it may be asked whether their adoption might not solve some of the transportation problems of Paris, in a manner infinitely less costly, and much more agreeable to the public, than such steam railways as are employed in London and Berlin." "The United States have 6000 kilometres of electric roads, which work with perfect regularity and without seriously modifying the appearance of the streets."

The "elevators" of the United States as seen at the Exposition attracted the pleased attention of the visitor; who speaks with commendation of those supplying the demands of the eighteen- and twenty-story buildings of the city, and of the great Otis Electric Elevator of the Liberal Arts Building of the Fair. Even the little devices for the transportation of "change," to and from the counter and the cashiers' desk in the American "stores," proved of sufficient interest to justify a word of praise. The rolling sidewalk and the Ferris wheel were thought admirable examples of good engineering.

M. Richard finds nothing new among the steam-engines. He notes that the American uses the non-condensing engine more generally than the European, and attributes this fact to the fre-

quent difficulty of securing condensing water, and to the still more usual fact that the buyer very generally expects, later, with improved business, to displace his first purchase by a larger and better machine. The stroke of piston is greater, proportionally to diameter, than in Europe. High-speed engines are coming into more general use, and more rapidly than in Europe. He remarks their solidity, fewness of parts, and perfect construction and alignment. Vertical engines for directly connected dynamos are the coming type. The great 3500 horse-power Allis engine is described, with its quadruple-expansion, and its special features. The great engines of the side-wheel steamer "Puritan" illustrate a peculiar phase of our marine engineering, with their paddle-wheels forty feet in diameter, weighing 100 tons, and driven by compound engines of 7500 horse-power. "These engines are admirably gotten up, work with perfect smoothness, and are very economical." The De Laval turbine is described, with its ingenious device of a slender springing shaft to permit self-adjustment to its natural axis, in spinning up to 20,000 revolutions per minute. Its economy is extraordinary; the machine demanding but nine kilograms of steam per horse-power per hour. The steam-engines for electric light and power distribution were of enormous number and power, and should have been installed, according to M. Richard, in a separate building, devoted entirely to motive power. Their noise, heat, and odors were very objectionable in the machinery building. The facts that the boilers were all of the tubulous type, fired with petroleum, and of over 25,000 horse-power were among the most striking observed at the Exposition. He found many petroleum engines, and steam-engines using petroleum as fuel, in the United States, and thinks the use of that fuel likely to solve many otherwise difficult problems.

Turbine construction attracted M. Richard's attention, and he finds the American turbines, usually of the inward and downward flow type, well-made, inexpensive, and efficient. The Pelton wheel was the greatest novelty. Our leather belts were, in some cases, of enormous size and of splendid quality. That of one of the Allis Engines, supplied by the Page Belting Co., was 44.5 meters long and 1.8 meters wide; transmitting 1000 horse-power at the rate of 30 meters per second. American windmills are curious and ingenious in all their various forms; the direct-acting steam-pumps are hardly less so, and our machine gearing is beautifully designed and made. The machine-tools illustrate

the best work in America; they are adjustable with mathematical precision, and so effectively apply the labor of their attendants that, notwithstanding the high price of labor in America, the product turned out is often cheaper than in Europe. The planer of the Niles Tool Works of Hamilton, Ohio, was a most notable exhibit; capable, as it was, of planing pieces 3.5 meters wide and of equal height; and its table traversing 9 meters, the head carrying four tools. Much more wonderful, even, than the great planer, is the mighty steam-hammer of the Bethlehem Steel Works, weighing 125 tons, and falling 5 meters. Its anvil weighs 250 tons. In use with this great hammer, also, is the hydraulic forging machine of the same company; which can produce a pressure of 14,000 tons, equal to the weight of a cube of water 25 meters on a side.

TESTS OF MAGNESIUM AND ITS ALLOYS.

S. A. BARRACLOUGH AND L. S MARKS.

Magnesium is a silver white metal of specific gravity of 1.74 and melting point 446° F. The metal used was obtained in the form of rolled or drawn rods about .43″ in diameter. Owing to the low temperature at which magnesium burns, it was not deemed advisable to attempt to cast it to standard test piece form, and so the rods were tested in tension just as they were supplied. Their length was about 8″, and the extension was measured over a length of 4 inches. The material gave a fine cup fracture. It is very tough and bends with ease, emitting a cry like that of tin. It is easily tooled both with the file and in the lathe.

The following table gives the results of the tension tests for pure magnesium:

Number of Test Piece.	*Diameter.*	*Breaking Load. lbs.*	*Breaking Load. lbs. per in.²*	*Elastic Limit. lbs. per in.²*	*Ductility. per cent.*	*Modulus of Elasticity.*
1	.433	3500	23800	8800	4.2	2,040,000
2	.433	3250	22050	——	—	1,860,000
3	.442	3200	20900	10780	1.8	2,060,000
4	.435	2900	19500	8400	2.5	1,830,000
5	.424	3500	24800	7090	3.1	1,930,000
6	.432	3300	22500	——	2.3	——

From the above table it will be seen that:

The average breaking strength is - - -	22250 lbs. per in. sq.
The average elastic limit is - - - -	8770.
The average ductility is - - - - -	2.8 per cent.
The average modulus of elasticity is - -	1,945,000.

It is noticeable that though the density of the metal is only two-thirds that of aluminum it has more than twice its tensile strength.

It was thought from the general similarity in properties of aluminum and magnesium that a series of valuable alloys of the latter might be found similar to those of aluminum, already in extensive use. In the present tests the attempt was made to form alloys with aluminum, copper, brass, bronze, and iron.

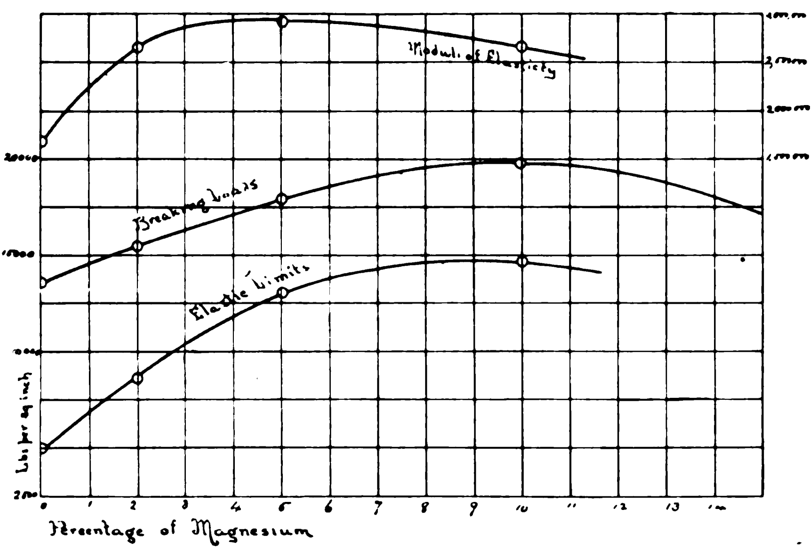
A satisfactory series of alloys with different proportions of aluminum was obtained and tested. The results are given in the accompanying table and are plotted out graphically.

Number of Test Piece.	*Percentage of Magnesium.*	*Breaking Strength lbs. per in.²*	*Elastic Limit.*	*Modulus of Elasticity.*
1	0	13685	4900	1,690,000
2	2	15440	8700	2,650,000
3	5	17850	13090	2,917,000
4	10	19680	14600	2,650,000
5	30	5000	——	——

The addition of magnesium in increasing proportions was found to make the alloy more brittle. With 30 per cent. of magnesium it was so brittle as not to show any elastic limit.

The attempt to form alloys with copper, brass or bronze, containing more than one per cent of magnesium were not successful. Several test pieces containing one per cent. or less were cast but in every case the presence of cavities prevented the exact determination of their strength.

No alloys could be formed with iron, the magnesium always appearing in the form of globules in the interior of the metal.



RAILWAY SCHOOLS IN RUSSIA.

It has been, for some years past, the intention of the Director of Sibley College, with the approval of the Trustees of the University, to establish at the earliest practicable date, a school of railway mechanics, with special provision of instruction in locomotive engine design and construction. This was proposed as one of the graduate departments contemplated in the organization of the college of mechanical engineering, originally, and has been kept in view constantly, since. As was stated in the reports of the Director, there has never yet been organized such a school in this country; notwithstanding the fact that the United States possesses the largest railway system in the world. constituting, as it does about one half the total for the world. The extent of our railway service, the number of people employed, the importance and difficulty of this department of machine construction, and the opportunity which it offers for scientific training of a large

body of engineers capable of aiding in the improvement both of the methods of construction and the efficiency of the service, at once constitute a reason for the establishment of such schools of engineering and give good ground for expecting that they would find a large constituency. The most able and experienced of the master mechanics, and of the superintendents of motive power of our most extensive railway systems have indicated their approval of the scheme and urged its prompt adoption.

It has, however, been left for Russia, generally considered the most backward of all European countries in scientific work in connection with advanced engineering, to take the lead in this great field of construction. There are, to day, in that country, nearly thirty technical schools devoted mainly to the instruction of young men proposing to enter the railway service. They are of a lower grade than those proposed to be here organized, and are in large part trade-schools ; but they constitute an important and useful foundation for the work on a higher plane attained by engineering schools, generally, in the United States. Twenty-five of these schools are sustained by the government ; as are, in Europe, nearly all the great technical schools. The others are kept under inspection by the government. The income of the governmental schools is derived from contributions from the earnings of the railways of Russia at the rate of about 15 roubles per Verst of their track. A charge is made of ten roubles per annum as a tuition-fee and some returns are obtained from the sales of work and materials from the schools. The capital of these schools amounts to about one and a half million roubles and the annual expenditures to about a half-million each year.

The course of school-instruction is of three years duration ; after which the graduates are given two years of formal instruction and practice on the railways into which they are finally admitted as employes, if found satisfactory in character and attainments. A shop course, including the principal trades, draughting, a continuous course of instruction in mathematics and the applied sciences, and especially in applications to railway work, constitute the main features of the work of these schools. Between 150 and 200 students are enrolled.

REPORT OF ENGINEER-IN-CHIEF MELVILLE, U. S. N. 1893.

The Annual Report of the Chief of the Bureau of Steam-Engineering of the Navy Department has been issued. The Engineer-in-Chief states that the famous old flag-ship of Farragut, the *Hartford*, is to have new, compound engines, which will save ninety-two tons weight and give an increased steaming range of about 900 miles. It is a question, among many engineers and old friends of the navy, whether the old ship should not be left absolutely unchanged, and preserved forever as a relic of our civil war, and, especially, of our most famous admiral. The new gunboats authorized are to have "quadruple-expansion engines," in one case, "triple-expansion" in the others. Torpedo-boats are to be built with quadruple-expansion engines and for 250 pounds steam-pressure. Weights have been brought down to sixty pounds per I. H. P.

Of the new ships tried during the year reported on, the *Monterey* excited exceptional interest in consequence of the discrepancy of reports relating to the performance of the coil-boilers with which, in part, she is fitted. The Engineer-in-Chief gives the facts, and states that at no time, and in no respect, did these boilers give any trouble or give rise to any danger, and that they have proved that it is perfectly practicable to work such boilers "in battery" with the ordinary forms of shell-boiler. They were intended, in this case, for use in times of emergency, when the utmost power of the machinery is called for. Mr. Melville states that should this class of boilers prove to be durable, they can be used for almost the entire boiler-power of naval vessels, with great saving of weight; thus permitting increased coal-supply, weight of armor or armament, or other gain in what may be considered the most essential quality of any given ship.

Among the valuable statistics and data distributed through the report may be noted the following: In the last five ships admitted to the service after formal trial, the *Monterey*, *Bancroft*, *Detroit*, *New York* and *Machias*, the indicated horse-power ranges from 9.75 to 13 per ton of machinery. This gives between 13.68 and 16.54 I. H. P. per square-foot of grate surface; it is from 1.89 to 2.81 square-feet of heating surface per I. H. P., and the condensing surface ranges between 1.20 and 1.54 square-feet per I. H. P.

The coal consumption is from 35 to 38 pounds per square-foot of grate and 2.44 to 2.53 per hour per I. H. P. All these engines are "triple-expansion." Their engine-power is smallest in the *Bancroft*—1183 I. H. P.—and greatest in the *New York*—16,947 I. H. P. The speeds attained range from 13.6 to 21 knots. The coal burned was, where stated in the logs, "Pocahontas, hand-picked." This is the same coal which was employed in the Sibley College trials of the Milwaukee Pumping Engine, now famous in the annals of "record-breakers."

A VALUABLE COLLECTION.

One of the most valuable and interesting of the exhibits at the Chicago Exposition, which have been turned over to Sibley College since its close, is the "educational exhibit of abrasives," as it is called, collected and arranged mainly by Mr. T. Dunkin Paret, of the Tanite Co., of Stroudsburg. It is seen just as it stood in the Mines and Mining Building at the Exposition, in the illustration forming the frontispiece of this number of the JOURNAL. It contains samples of every form of abrasive used in the arts, by either civilized or barbarous nations; including, especially, every kind of material employed in making emery, corundum, and other familiar forms of grinding wheels. Emery is shown in all states of preparation, and in all grades, and corundum, sapphires, pumice and rotten stone, illustrate the various grades of hardness demanded. The products of the grinding machine are also shown, beside those of the chisel and the file. It is seen that, in one example, the emery wheel did 126 times as much work on saw-plate as did the file, for example. In the case and on the ends of the stand are numerous parts of machines, all of which have been surfaced by the Newman Emery Planer. These appear to be as true as if planed, and tabulation shows that this machine has taken a maximum cut $\frac{1}{4}$ of an inch deep, and has taken a $\frac{1}{16}$ inch cut over a surface of 100 square inches in 6 minutes and 9 seconds. Its ordinary cut is from $\frac{1}{64}$ to $\frac{1}{32}$ inch.

Carbon, black and clear diamonds, "carborundum," "crushed steel," mill-stones, including French burr, and many curious abrasives from foreign lands are shown, among which are the following: Leaves of the Afeen Plant, used to clean gourds, after

the manner of sand paper ; contributed by Bolding Bowser, Esq., U. S. Consul, Sierra Leone, Africa. Wood of Agave Polyacantha, used for razor strops, contributed by Wm. P. Pierce, U. S. Consul, Trinidad. Dutch Rushes, or Scouring Rush [Equisetum Hyemale], from Yorkshire, England, supplied by David Brodie, M. D., London ; and Rush for same purpose, furnished by John Selwood, Stroudsburg, Pa. The epidermis of these plants is formed of silica, and the rush is used to polish wood and metals. Shark skin is contributed by the Tanite Co. This is to be used in the same way as emery cloth and sand paper. The collection is full of instruction for the young engineer.

OBITUARY NOTICES.

There have lately died, within a very short time of each other, three men, whose names will take their places among those of the foremost men who have been instrumental in forwarding scientific researches, theoretical and practical. On account of their high places in engineering circles, and also for their interest in Cornell University, we give short accounts of the life of each one :

MR. STEPHEN WILCOX.

Mr. Stephen Wilcox, of the Babcock & Wilcox Co., died at his home in Brooklyn, N. Y., November 27th, of pneumonia, after a very short illness. He was one of the best-known and most successful inventors this country has produced, and one of the ablest designing and constructing engineers.

Mr. Wilcox was a native of Westerly, R. I., as was his partner, Mr. Babcock, and acquired his skill in construction in the then famous shops of that town. His genius as an inventor was inborn. One of his earliest patents was a steam-boiler, in which a nest of inclined tubes was placed beneath a cylindrical shell, and the two connected by water-legs. This was the first of the boilers of that now familiar class, and the later Babcock & Wilcox boilers have been developed by a process of evolution, as their inventors say, by the partners. After many years of struggle, the new type of "safety-boiler" was finally introduced to the market, and the sales have, during recent years, been enormously great, and have made the inventors wealthy,

and all connected with the manufacture have enjoyed very handsome profits.

Mr. Wilcox gave much attention, about 1860, to the construction of air-engines, patenting a form of furnace-gas engine which had great promise. The inherent difficulties of that type of engine, however, proved too great to permit commercial success, and, after many ingenious modifications, embodying some valuable devices, it was given up. The two partners also organized the New York Safety Steam Power Company, for the purpose of building and marketing their steam engines, usually in small powers; and, after that firm had become successful, they disposed of it to others, and it is still doing a good business and with increasing reputation and sales. During the last few years Mr. Wilcox has given his attention mainly to the experimental development of the steam-engine, and a form of marine boiler for high pressures; building steam yachts in which to employ them, and thus combining experimental investigation with pleasure, in a manner most agreeable to both himself and his friends. He has constructed triple and quadruple expansion engines, for use with steam at 200 and 225 pounds pressure, and with very satisfactory results.

Mr. Wilcox was a skilled designer, an ingenious inventor, a sound constructor, and, as a man of business, both prudent and enterprising. Personally, he was one of the most lovable of men; warm hearted, loyal to his friends, sympathetic and benevolent, interested in the public weal; he made friends and held them wherever he went. One of his favorite pleasures was giving his old friends among his townspeople annual excursions on his yachts, which were kept busy during a good part of the season in this duty. He gave to the town of Westerly a fine public library building, and found great pleasure in superintending its erection. He was a life-member and charter-member of the American Society of Mechanical Engineers. He has always felt and freely expressed great interest in the work of Cornell University and of Sibley College and both partners have done much to promote that work.

PROFESSOR TYNDAL.

Dr. John Tyndal, the eminent chemist and physicist, died at Haslemere, England, December 4th, last. He was born at Leighlin Bridge, Ireland, of old North Irish stock, August 24th, 1820.

At nineteen, he was assistant engineer on the ordnance survey; worked, later, three years on railway construction, and then became a teacher in Queenwood College, Hampshire. He went to the University of Marburg, with Professor Frankland, in 1848, to study chemistry with Dr. Bunsen, and, subsequently, took up physics with Gerling and Knoblach, and mathematics with Stegmann. His first paper was published in the *Philosophical Magazine* in 1850, "On Magneto-Optic Properties of Crystals." He went to Berlin in 1850 to work with Professor Magnus, returning to London in 1851; and, meeting Faraday, with him, carried on some work of investigation. In 1853 he became professor of natural philosophy in the Royal Institution and in the School of Mines. From 1849 to 1859, he studied the glaciers of Switzerland, and his papers revealed the method and rate of flow of those solid streams. His study of radiant heat, begun in 1859, led to the production of his famous "Heat as a Mode of Motion" in 1863; In 1872 he came to the United States and delivered thirty-five lectures, the income from which, some $13,000, was given to sustain the scièntific scholarships assigned by Harvard, Columbia, and the University of Pennsylvania. His researches on "spontaneous generation," in 1875–6, were among the most remarkable of his investigations, and thoroughly discredited that, at one time, popular theory. Professor Tyndal married, in 1876, the daughter of Lord Hamilton. He had no children.

Professor Tyndal was one of the greatest scientific men that Great Britain has ever produced. He displayed his consumate ability, especially, in the ingenuity of his methods, and in contrivances for experimental investigation. This talent was peculiarly displayed in his researches on spontaneous generation and in radiant heat; where the most abstruse questions, and most obscure natural phenomena, were investigated by correspondingly original and ingenious processes and apparatus. Tyndal was the greatest popularizer of scientific knowledge the world has ever seen. His little book, "Heat as a Mode of Motion," found circulation throughout the civilized world, and its simple language, clear descriptions, and wonderfully interesting and beautiful style, carried to the minds of the least well-informed, if intelligent readers, a realization of scientific facts and principles such as many professionals lack. Personally, he was a man of pronounced opinions, a foe to all quackery and humbug, antagonistic in a most intense degree to everything which looked like

degradation of science to the mere purposes of commerce; but always glad to find useful applications of science in the promotion of the interests of the people. He was a strong promoter of technical education in all grades; but especially the popularization of pure science, and its cultivation for its own sake. He was generous, loyal to his friends, patriotic, and faithful to every duty, as a man, as a relative, and as a citizen. He made and held fast many friends; while his work made his name universally popular and gave him innumerable unknown friends among the people. Like his predecessors, Davy and Faraday, he has earned immortality with the people, as well as among scientific men.

GEORGE H. BABCOCK.

Mr. George H. Babcock, non-resident lecturer in the Sibley College courses on steam boiler construction, and one of the inventors of the Babcock & Wilcox boiler, died at his home in Plainfield, N. J., December 16th. His health had not been good for a number of years and his chronic disease finally terminated in acute form and he died, at the last, somewhat suddenly. He was engaged to lecture at Cornell in the spring-term of the present college year.

Mr. Babcock was born at Otsego, N. J., June 17, 1832, inheriting unusual talent as an inventor and as a mechanic from his father. His earliest adventures in business included the opening of the first printing office at Westerly, R. I., where he made his home, principally, for many years. He also started a publication, *The Literary Echo*, which still exists as *The Narragansett*. With Mr. Charles Potter, he organized an establishment for the manufacture of printing presses. Mr. Babcock, later, withdrew and went to New York, where he was employed by Mr. J. D. Stetson, a distinguished patent attorney, and while thus engaged taught classes in mechanical drawing in Cooper Union; exhibiting his very exceptional skill in that direction in a most satisfactory manner. Later, he entered the employ of the Mystic Iron Works, and, a few years afterward, the Hope Iron Works, at Providence, R. I.

While in the last named establishment, acting as chief draughtsman, he brought out a new form of expansion-gear for steam-engines, and, at about the same time, Mr. Stephen Wilcox, another Westerly mechanic, brought out a new form of steam-

boiler. Joining forces, the two inventors entered into a partnership which was only terminated by the death of Mr. Wilcox, November 27th, last, a little in advance of that of Mr. Babcock.

Mr. Babcock was a past president of the American Society of Mechanical Engineers, the President of the Plainfield Board of Education, and a leading and active member of the Seventh Day Baptist Church. He leaves a wife and one child—a boy who, he hoped, might, some day, be educated at Cornell University. Mr. Babcock was a student, as well as an inventor and mechanic, reading widely and with excellent judgment; he was broad in feeling, principle, and faith, wise in all the common walks of life, and learned in his profession. He was, as a man, devout and honorable, hating little meannesses as well as the larger crimes; honest and trustworthy in every business transaction; his word was as good as his bond, and his bond was always well-secured. He was charitable and philanthropic. He gave freely to the poor, assisted the needy, contributed liberally to the church and to education, and was as free in giving of his own time and strength as of his wealth, to every good object. He was in all ways an honor to his profession and to humanity.

BOOK REVIEW.

The Corliss Engine, by JOHN T. HENTHORNE, and *Its Management*, by CHARLES D. THURBER. 16 mo. 96 pp. $1.00. Published by Spon & Chamberlain, 12 Cortlandt St., New York.

This little book, now in its third edition, is an exceedingly useful one to engineers. giving, as it does, many hints and much practical information concerning the setting-up and management of the Corliss engine. Under the first part, which treats of the engine in general, Mr. Henthorne takes up and discusses many of the points to be considered by those interested in these engines. He begins by showing when steam jacketing is valuable and when it is not. In the two succeeding chapters he points out the characteristics to be considered in judging indicator cards for economical operation of the engine. He describes valve-setting in detail, as applied to this form of valve-gear, and carefully explains the method of construction of engine-foundations. Besides the above points he treats of lubrication, the air-pump, the driving-

gears, and the economic use of exhaust steam. All the chapters are well illustrated with numerous plates. The only adverse criticism we would pass is that in some places the method of expression is not clear, making it difficult to grasp the author's full meaning.

Under the second part Mr. Thurber gives his readers the benefit of his experience in the care and management of the engine, furnace, steam connections, governor, and other adjuncts of the plant, in a way that is at once interesting and instructive. This is followed by an appendix containing useful tables of horsepowers and dimensions. On the whole, the book is a useful one and would be a wise addition to an engineer's library, if he does not already possess it.

—Considerable attention has been attracted of late to the steam turbine invented by Dr. Gustav De Laval of Stockholm, Sweden, and known as the De Laval Steam Turbine. Numerous tests have shown that fairly good efficiencies can be obtained from even small turbines, and in the case of machines of considerable size, the efficiency is said to be fully equal to that of high-grade triple-expansion engines of a corresponding size. In using the steam in the turbine a much more complete expansion is obtained than in the case of the steam engine, for the pressure is allowed to fall from that of the boiler to that of the atmosphere before being applied to the wheel. This is accomplished by expanding the steam pipe just before the wheel is reached, the result being a highly increased velocity and volume of steam. In a five H. P. turbine a speed of 30,000 revolutions per minute is reached, giving a peripheral velocity of 574 feet per second. The shaft is made flexible and placed in movable bearings so that it will accommodate itself to any tendency the wheel may have to get off centre.

—A student, recently graduated, and who has entered the United States Patent Office, writes the Director of Sibley College:—"If a man wants to study patent law, I think this is the best place for him; but for one intending to follow engineering, it is not at all desirable unless he can get into the electrical or mechanical engineering division, and this is very difficult to accomplish."

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EDITORIALS.

"THE World's Columbian Exposition has come and gone." Nearly, if not quite, all of the immense numbers of publications printed every day, week, and month, throughout the country, have regaled their readers with news concerning the great exhibition. The dailies have had their columns full, for nearly a year, of news, first concerning the preparation for the Fair, next, concerning the sights and scenes at the Fair, and finally concerning the closing-up and clearing away of the plant, if we may so call it—the railroads, bridges, buildings, etc.,—of the Fair. The weeklies, especially the pictorials, have published issues illustrating

some of the innumerable interesting sights to be seen at this great exhibition. The monthlies have issued special World's Fair numbers, full of valuable matter, and have illustrated them profusely and artistically with plates made from photographs and sketches by special artists. The latter class of publications is a particularly valuable one to its readers. As to those chronic kickers who always find fault with everything under the sun, and who, in this case, say that they are "tired of World's Fair, the subject is worn threadbare," if they would stop to consider the magnitude of the great fund of information thus laid at their feet, and its value, not only to those who did not attend the Fair, but to those more fortunate ones who did, they would cease to scoff and begin to read.

The engineering press has not been behind the general press in its reports of matters of interest concerning the Exposition, and it possesses added advantage that its matter has been of vital importance to its readers, as marking the advances in the various lines of engineering research. It is absolutely necessary that an engineer should keep up with the times. Prominent among the latter class of publications stands the *Engineering Magazine*, the January issue of which forms its World's Fair number. It is entitled "The World's Fair in Retrospect. Specially designed to illustrate the practical value of the World's Columbian Exposition to the science and industry of the time." Every article that it contains bears upon the wonderful advances made in the development of the industrial arts and sciences. Among them we may mention one or two as specially attractive. Andrew Carnegie has contributed a paper upon "The Value of the World's Fair to the American People." Dr. Thurston, in an interesting article entitled "An Era of Mechanical Triumphs," presents strongly the great strides in this direction of late years. He has gathered and placed before the reader a large number of facts, each of which in itself is interesting, but when thus put in the form of a connected article, they offer a wide field for thought on the part of the thinking reader. Professor Elihu Thomson traces, under the head of "Electricity in 1876 and in 1893," the development of this branch of science, in a manner that is at once delightfully entertaining and extremely instructive. In scanning the magazine, the eyes are feasted upon numerous artistic pictures, consisting of nearly one hundred pages of illustrations of buildings, exhibits and scenes at the Fair. This issue is in fact, as in name, a Souvenir Number.

ELECTRICITY is applied to so many and so varied purposes in these days that a new application scarcely excites comment, however novel it may be. The ingenuity of the designer is at work, principally to provide means whereby the electric current may be transmitted from a central station to small outlying power-consumers; but little is being done towards applying the primary battery, placed near the motor, to the same purposes, on account of its uneconomical operations. However, one interesting use of the primary battery has been made in furnishing the power to operate clocks. The Waterbury Clock Co. has lately placed in its building in Waterbury, Conn., a new tower clock, the motive power of which is a battery of ten sal-ammoniac cells. It is said that these cells are sufficiently powerful to run a clock for a year without it becoming necessary to renew them. A great saving in required power is effected, however, by a reduction in the weight of the driving mechanism of the clock to one-fourth that of an ordinary clock driven by weights, and consequently a large frictional loss is obviated. Also the driving force is exerted more effectively under the new system than under the old.

AN ERA OF MECHANICAL TRIUMPHS.

It is sometimes argued that inventions of new and improved forms of machinery and labor-saving devices are an evil, because they throw out of employment men who otherwise would be occupied in making the articles or doing the work now done by the improved machines. While it is undoubtedly true that considerable immediate hardship often is created by the introduction of a new machine, owing to the fact that a number of laborers are thrown out of employment, still in the end good is brought about, for these operatives soon turn to something else, and the total amount of work done by the laboring class is increased. When this occurs working hours are shortened, and the price of products decreased, thus bettering the condition of the laboring class by giving them more leisure and giving their wages greater purchasing power. Dr. Thurston has stated some facts so pertinent to this question that we take the liberty of quoting from his article, "An Era of Mechanical Triumphs," a few of the interesting points, changing his order, somewhat, to suit our purpose. He says:

"In a generation the wealth of the civilized world has doubled and mainly to the advantage of the poor and less wealthy classes. Wages have doubled, and the purchasing power of the dollar has

in most cases and on the average, increased 50 per cent. and more. . . . . Where, as in cotton-spinning, a man can now do, with the aid of machinery, four or five times the work that he could have done a half-century ago, and can obtain twice the wage for his shorter day's labor, it is obvious that the world must, on the whole, have gained enormously in wealth, comfort, and happiness. And this has come largely of this direct stimulation of production due to the introduction of modern inventions and machinery, and largely, also, of that diversification of industries which the resulting increase of wealth and available time has rendered possible. . . . . . The steam-engine has come to carry the whole weight, practically, of modern civilization. It does the work of a thousand millions of laborers, three or four times the working force of the world; it transports a thousand tons a thousand miles, in the modern steamship, at a cost of 15 tons of fuel; it consumes a pound or two of fuel and utilizes the dormant energy thus awakened in any direction in which its aid is desired, in the performance of a full day's work of an able-bodied man . . . . . . In the times of Adam Smith, a century ago, ten persons made 48,000 pins in a day. A hundred years later, seventy machines, with three men in attendance, aided by the brain-work of some hard-handed demi-gods, produced 7,500,000 better pins. . . . . . A century ago President Washington wore, at his second inauguration, woolen cloth costing $5 a yard, made up in a woolen factory then recently established; while his family, like all others in the land, were clothed principally in homespun. Similar goods would probably now cost $2 a yard, and the people are clothed in the product of the power-loom, then unknown, and only invented two generations later. . . . . . The practical outcome of this revolution of a century has been the promotion of the welfare and comfort of the whole world, the elevation of races to higher planes of life, the advancement, not only of the material interest of the world, but also the intellectual and the moral life of its people. With the relief from the necessity of daily and incessant drudgery comes the power of devoting a part of life to thought, to self-improvement, to enjoyment of the comforts and of the luxuries, physical, intellectual, and moral, which the new life offers. . . . . . At the prices to-day current, in many cases, the workman secures by a day's labor double the amount of food and clothing that he could have obtained then, and in many cases he is able to procure what the wealthiest could not have obtained at any price a generation or two earlier."

THE subject of belt transmission vs. electric transmission for transmitting power from the central unit of a factory to the several small power consumers in the shape of machines scattered throughout the plant, is one which is attracting the attention of manufacturers to a considerable extent, in these days. That the electrical method of transmission is practicable is an indisputed fact, but until it is thoroughly demonstrated either that it is more economical than the method now in vogue, or else that, being equally as economical, it possesses other advantages, is will not take the place of belting used for this purpose. The experience of a number of American firms with this form of transmission seems to show favorable results. A Belgian correspondent of *Machinery* writes of an application in the case of a factory in that country, where especially satisfactory results were obtained. A 600 H. P. dynamo furnishes the current for 16 motors, ranging from 16 to 37 H. P., placed in the shops, and there operating the machines in groups. The efficiency of the system of dynamos, conductors, and motors is about 70 per cent. Since the loss in belt transmission generally is considered to be the same at all loads, we see that if at full load the efficiencies of the two systems were the same, then as the load fell off the electrical would continually gain relatively to the mechanical. In the case of the above mentioned factory it was found that more power was needed to drive all the idle machines than was necessary to drive the shops under ordinary working conditions. It is only a step to pass from this subdivision of power units to a system where each tool shall be driven by its own motor, and it is well within the realms of possibility that the present generation will see this done, especially in the case of large tools.

As instances where this application has already been made, we may mention the hydraulic coining-press operated by a three-throw electric pump, which has been made by Wm. Sellers & Co. for the U. S. Mint at Philadelphia. Also, the Buffalo Forge Co. is now building blowers which are very satisfactorily run by direct-coupled electric motors; and numerous electric drills and pumps are in use, especially in mining.

THE great success of the intramural railway at the fair has furnished an impetus for the establishment of elevated electric railways that undoubtedly will lead to the building of numerous others in the near future. There is now one in operation in Liv-

erpool, England, completed during the past summer, in which a rather unusual method of transmitting the motive power is employed. It is a modification of the third-rail system sometimes suggested as a feature of high-speed travel. A rail is laid on, but insulated from, the ties, half way between the track rails and a brush supported from the truck frame, bears upon the middle rail, thus fulfilling the same function as does the trolley of the ordinary system. The rail carrying the current is a little taller than the other rails to facilitate crossing other tracks.

WHEN we are told that the United States has within its borders a total of over 175,000 miles of railways, we have to stop a moment to consider the full meaning of the statement. It is difficult to grasp its importance, but we will obtain some faint idea of the magnitude of the business by looking at the resources of just one company supplying just one of the necessities of railroad travel. The Baldwin Locomotive Works of Philadelphia employ 5,000 men, who by their work are building 1,000 locomotives every year, besides repairing a large number. If it be remembered that to this number must be added the output of all the other companies manufacturing locomotives, we begin to realize the amount of railroad travel that is represented by such an enormous demand for the motors. One railroad alone, the Atchison, Topeka and Sante Fe, has recently ordered 71 locomotives.

THE subject of accidents due to the "deadly trolley" is one which has been much discussed ever since electric traction came into vogue. The newspapers are never tired of telling of the awful disasters caused by the electric car, some even going so far as to publish a daily record of all accidents attributable either directly or indirectly to these vehicles. For some time a discussion has been going on in the *Electrical Engineer* concerning the reasons for such accidents as can justly be credited to the electric railways and the methods by which the danger may be lessened. Nearly all of the writers agree that the motor-man must have, at his command, means for controlling the car as completely as possible, and that he must know how to apply his resources when the time comes. Various plans for effecting this control have been suggested, among which we may mention those depending for their action upon a reversal of the motor, those depending upon some form of electro-magnetic brakes, and those depending upon com-

pressed air or vacuum brakes. Objections are found to the first class on the score of their racking the motor to pieces, and to the latter classes because they introduce undesirable complexity of mechanism. The result of discussions of this nature can not fail to be beneficial, and in this case the result undoubtedly will be to bring about much better control of electric cars for high-speed municipal service.

A GREAT deal has been said and written concerning the experiment which was lately tried on the Erie Canal of propelling canal-boats by electric motors, to which current was transmitted by over-head trolley wires. It seems to be the opinion of those who are competent to judge, however, that the trial was of very little practical importance, in so far as the solution of the problem is concerned. It is known now that canal-boats can be propelled by electric power, but that is no more than was known before the experiment was tried. The apparatus used in the recent experiment was faulty in several respects, and throughout the trial was inadequate to demonstrate the entire practicability of the method of propulsion. The whole affair was successful as a big advertisement, however, and was worth the trouble for that reason alone. It is quite probable that in the future, with improved methods specially adapted to the purpose, electric canal-boat propulsion may be made a practicable and profitable undertaking.

CRANK SHAFTS.

—The French government has just completed a light-house that has the very desirable feature of needing attention only once in two months. It burns an oil lamp whose action is entirely automatic, the oil being contained in a reservoir having a capacity of 100 quarts, and the wick being fed to the flame by a self-regulating device.

—Three pneumatic guns are being built for the United States government. They are thirty feet long, fifteen inches in calibre, and will throw a charge of dynamite weighing 500 pounds a distance of two and a half miles once every two minutes. The air-pressure is automatically cut off in such a way that the range can be made any desired distance up to the limit of gun.

—The field of the electric railway is an ever increasing one.

We have in our own city a mail and baggage car, and throughout the country cars have been used for various purposes other than for regular passenger traffic. Perhaps one of the most unique of these is the funeral car, lately built for a cemetery of San Francisco. It is thirty-nine feet long, is richly furnished, and cost $2,500.

—The largest refracting telescope in the world is the one made for the University of Chicago by Warner & Swasey, and by them exhibited at the Fair. The object glass (as yet unfinished) is forty inches in diameter. The tube is of steel, sixty-four feet long, fifty-two inches in diameter at the center, and weighs six tons. The polar axis is a steel shaft fifteen inches in diameter, thirteen and a half feet long and weighs three and one-half tons; the declination axis is also of steel, being twelve inches in diameter, eleven and a half feet long, and weighing one and one-half tons. The clock-work, for keeping the instument focused on a star during observations, weighs one and one-half tons, and by its operation moves a weight of twenty tons. Electric motors are used to wind the clock. The total weight of the whole instrument is seventy-five tons.

—A rather unusual method of employing arc lamps for lighting purposes has been in use in a cotton-mill in England for the past twelve months and has given a high degree of satisfaction. The lamps consist of two carbons of unequal diameters (to avoid complex feed mechanism), placed vertically, the smaller, having a diameter of 0″.2, being placed above the larger, whose diameter is 0″.486. A cone-shaped reflector, 25″ wide at the top and 7″ wide at the bottom, and covered on the inside with white enamel, is placed under the carbons to direct the rays upward. Also, the current is passed from the lower to the upper carbon to cause the lower to become cup-shaped and so cast rays upward. The illumination is affected by the light reflected up from the lamp to the white ceiling and thence to all parts of the room. It is found that the system is very efficient and entirely satisfactory except in casses where the ceiling is too high. One peculiar circumstance in connection with the light produced is that no shadows whatever are cast.

—*The Engineering News* of November 30, referring to the importance of their duties, and of the work performed by engineer-officers in the navy, says:—"It is impossible to refrain from remarking that the judgment, technical knowledge, and mechanical

skill that can produce a "Columbia" should, with comparatively little added knowledge of routine work, be also fully equal to the task of commanding and fighting her, in any emergency. The converse is certainly true; that the line-officer, as compared with the engineer, would have to add an immeasurably greater volume to his general stock of nautical knowledge before he could either design or practically handle his ship. A long time would probably elapse before all fighting officers aboard ship will also be engineers; but each new achievement of the staff-engineer corps is making it more evident that they are altogether deserving of a higher official standing than present law permits, and that any existing prejudice is a relic of a condition of affairs that has passed away forever, as far as the modern navy is concerned."

PERSONALS.

'90.

A. H. Herschel has an excellent position with the Westinghouse Electric Manufacturing Company.

'91.

Geo. M. Brill is employed by the Solway Process Co., of Syracuse, N. Y.

'92.

Geo. H. Davis is with the White Engineering Co. of New York City.

E. F. Aldrich holds a responsible position with the Dodge Split Pulley Co. of Wishawka, Ind.

Edw. Everett Clark is superintendent of the shops and industrial arts department at the Elmira Reformatory.

Burton N. Bump is a much valued employe of the Finch Manufacturing Co. of Scranton, Pa. Fred J. Platt is also at Scranton, Pa., installing electric mining machinery in neighboring mines.

T. B. Corey has recently left the Elektron Co. to accept a position with the A. B. See Mfg. Co. of Brooklyn, N. Y., manufacturers of electric elevators, where he has charge of their electric department.

'93.

C. L. Jeffrey has a position with the Rhode Island Locomotive Works, at Providence.

F. L. Cross is a valued man in the employ of the Central Electric Heating Co. of N. Y. City.

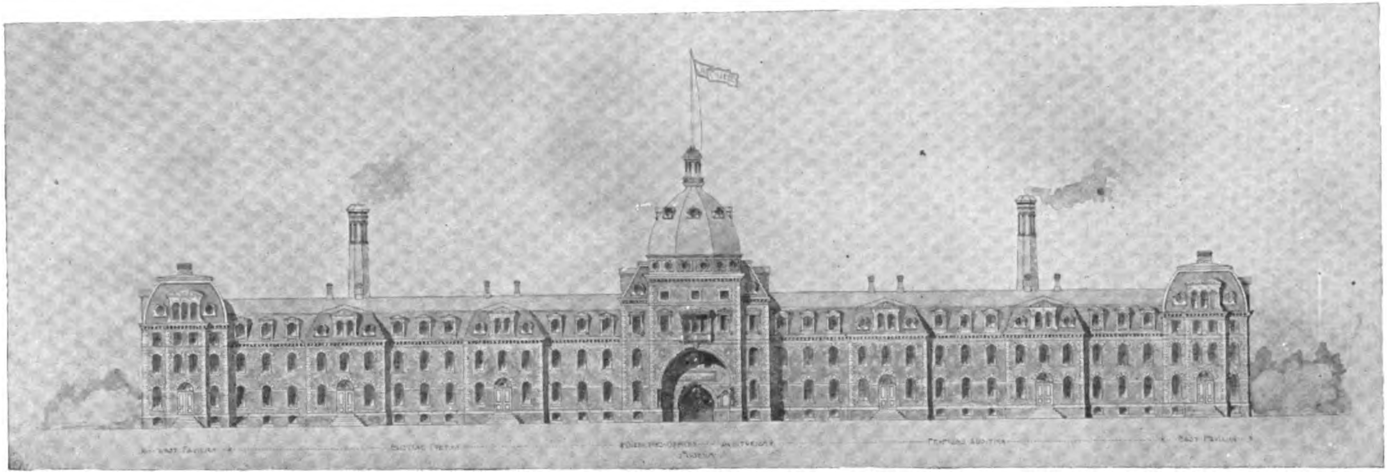
F. R. Frost, who was of the electric light staff at the World's Fair, has returned to the University for some higher experimental investigation.

C. W. Roess holds a position with the National Transit Co. of Oil City, Pa., and is employed erecting and operating their large oil pumping plant.

K. B. Miller is now in the patent examining corps of the U. S. Patent Office, where he has already gained an enviable reputation for rapid and accurate work.

W. W. Sibson, not Gibson, as inadverdently appeared in our last issue, is secretary of the New Jersey Art metal Co., Passaic, N J. He is also a member of the company.

W. F. Ballantyne and R. B. Williamson, Sigma Xi of '93, are with the Elecktron M'f'g. Co. of Boston, Mass., and with the Hyer, Sheehan Motor Co of Newburg, N. Y., respectively.



SIBLEY COLLEGE WHEN COMPLETED.

THE SIBLEY
JOURNAL OF ENGINEERING.

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IN CORNELL UNIVERSITY

"The leading object shall be, without excluding other scientific and classical studies, and including military tactics, to teach such branches of learning as are related to Agriculture and the Mechanic Arts, in such manner as the legislatures of the States may respectively prescribe, in order to promote the liberal and practical education of Industrial Classes in the several pursuits and professions in life."—[An act donating public lands to the several States and Territories which may provide Colleges for the benefit of Agriculture and the Mechanic Arts, July 6, 1862.]

SIBLEY COLLEGE.

The history of Sibley College begins with that of the University, in 1868. Its start was humble, the register at that time showing that twenty-seven out of the four hundred and twelve students of the University were enrolled in the Engineering department. The shops, the equipment for which consisted of one small lathe (still preserved in Professor Morris' office) and a forge, were temporarily fitted up in the old Civil Engineering building, as were also the museums, laboratories, and drawing rooms. During the two years that followed, the material equipment was increased by the addition of machinery and models, and the faculty organization was completed with Professor J. L. Morris as the Dean. It was at this time that the Hon. Hiram Sibley, of Rochester, N. Y., gave to the University, at a cost of thirty thousand dollars, the original building of the college which bears his name. The foundation of this building was laid in the autumn of 1870. It was completed during the following summer, and the dedication took place on June 21, 1871. The ceremonies included addresses by Professor D. C. Gilman, President of Johns Hopkins, Governor Hoffman, President White, Hon. Ezra Cornell, Hon. Erastus Brooks, and others. Between the years 1870 and 1884 Mr. Sibley made gifts amounting to nearly two hundred thousand dollars, which were devoted to the erection and extension of buildings, the purchasing of new machinery, etc. The growth of

the department was accompanied by an increase in the number of students, until, in 1875, fifty-six were numbered on the rolls. During the next decade a decrease in attendance and subsequently an increase took place, so that, in 1883, the number was about the same as it had been in 1871. Up to this time, no instruction in forging or wood-working had been offered, but in this and the following year shops for work in these branches were built and equipped. In 1885, Dr. R. H. Thurston, then Professor of Mechanical Engineering in the Stevens Institute of Technology, accepted the office of Director of Sibley College. Before this the University had paid only the operating expenses of the Department, but now it made an appropriation of twenty-five thousand dollars and placed it at the disposal of the College. Under Dr. Thurston's administration Sibley College has been wonderfully prosperous; new buildings have made their appearance, new equipments have been added to shop and laboratory, and, still more indicative of progress, many new students have sought the advantages here offered, in such large numbers, that, notwithstanding the gradual increase in entrance requirements that have been made from time to time, Sibley College has found its material growth too slow to satisfy the demands upon its resources. The result has been a continually over-crowded condition of the Department. The attendance has increased from fifty-one in 1883 to nearly six hundred in 1893, and the struggle to accommodate this large and steadily growing body of students has been equally severe, in adjustment of schedules of study, in advancing the requirements for admission, in elevating the once comparatively low and non-professional course to the position of a distinctively professional one—so far as we know, the first and almost only purely professional course taught in any professional engineering school at home or abroad—and in securing suitable and competent professors and instructors. It has been none the less difficult, also, to find place for the needed equipment so generously supplied by the authorities, and, still more considerably, though not more generously, by outside friends, and to give the teaching force space for lecture and class-rooms and for museums and laboratories. This has only been accomplished by taking the museums for class-rooms and lecture-halls, and the cellar for a modelling room and experimental laboratory in marine construction and engineering; while the laboratories have been found place in space ravaged from the workshops, though needed seriously there, and by building sheds over such pieces of machinery as could not be

found place inside the buildings. Of the pile of structures planned before the death of the founder, the old "main building" constitutes an East wing, the new construction a West wing; and the West central portion, with its lofty dome, remains still unbuilt.

An immense relief at last is now afforded by this new building, just completed and in process of fitting up and furnishing, given the college by Mr. Hiram W. Sibley. We present in this issue a picture of the coming Sibley College, as contemplated in the designs of the architect. In dimensions of front the recent addition is similar, as also, in design and appearance, to the old building; but it is five feet deeper, correspondingly more capacious, and more than correspondingly satisfactory in plan and proportions of rooms, as well as in those essentials of successful working-space, heating and ventilation. The architect, Professor Osborne, has given the University more for the money appropriated, probably, than it ever before received in any structure on the Campus. It is simple, but substantial, neat, and impressive in exterior, well arranged and ingeniously planned within. It is built on the semi-fireproof system characteristic of the best New England mill-construction, and is thus practically really fireproof. The front is of stone, matching that of the older main building, and the remainder of the structure, interior and exterior, is of brick. Floors and roof are of heavy plank, and there are no air-spaces, all fillings between floors and ceilings being complete and of cement. The lower floor contains large museum space, and a fine lecture-room; the second floor, drawing-rooms and lecture-rooms for the upper classmen, and the upper floor is similarly fitted up for the Sophomore class and its instructors. All the instructors have good offices and private working rooms; and the classes themselves have fine, large, and well-ventilated drawing-rooms, with good light, and ample heating power in their steam supply. The basement will be used, for the present, in large part, for the work of the Department of Experimental Engineering, a department which demands much more space than has ever yet been available, and which can probably never have precisely that extent and kind of room, and those special facilities for work, which that exceedingly important and fruitful and most impressive among all the departments of Sibley College requires, until it shall have a large and well-planned building precisely suited to its peculiar needs. That has been, for a long time, a pressing need; it is to-day the most urgent necessity in this part of the Sibley College scheme. This demand is most pressing in that

part of the work which is taken by the seniors and graduate students, which latter, once unknown in engineering schools, has come to be at Sibley College, a very large and growing body of most admirable men. But every student and alumnus and all friends of the University and of the college will be glad to know of this last great contribution by the son of the founder, to the facilities of Sibley College.

MAXIMUM CONTEMPORARY ECONOMY OF THE MULTIPLE-EXPANSION STEAM ENGINE.

WITH A COMPARISON OF ITS EFFICIENCY WITH THAT OF ITS IDEAL REPRESENTATIVE, UNDER SIMILAR EXTERNAL CONDITIONS.*

BY ROBERT H. THURSTON.

(Member of the Society and Past President.)

In the issue of this JOURNAL for June, 1893, we gave the essential data and results of a formal trial of the Milwaukee Pumping Engine, in exceptionally complete extent and accuracy in detail, as conducted in behalf of Sibley College, at the request of the Director, by Professor Carpenter and a "crew," from the class of '93 and the graduate list, and checked by representatives of the City of Milwaukee, in the engineering department, and of the designer and the builders, Messrs. Reynolds and the E. P. Allis Co. of Milwaukee. We are now able to add to the figures and results there given the final deductions made after the completion of the investigation of the thermodynamic and economic conditions of the operation of this remarkable engine, and which establish it as the most efficient engine yet given complete trial and placed on the record. The figures below now stand as the measures of "the maximum contemporary economy of the high-pressure multiple-expansion steam-engine" for the year 1893.

These figures are : †

Foot-pounds of work for 100 lbs. dry coal	*143,306,470*
" " " " " " wet "	135,770,000
" " " " " " combustible	145,438,000
" " " " 1,000 lbs. feed-water	152,448,000
" " " " 1,000 " dry steam	*154,048,000*
" " " " 1,000,000 B. T. U.	*137,656,000*
" " " " 1 cwt. coal (112 lbs.)	152,630,000
Kilogrammeters of work per kilo of coal	429,110

* Presented at the New York Meeting (December, 1893), of the American Society of Mechanical Engineers, and forming part of Volume XV. of the *Transactions.* [Abstract.]

† Sibley Journal, June, 1893.

While the thermo-dynamic results are :

Thermo-dynamoic efficiency		0.18727
Heat per *I. H. P.* per hour, and per minute, *B. T. U.* . .	13,056 ;	217.6
Steam per *I. H. P.* per hour, lbs		*11.678*
Fuel per *I. H. P.* per hour lbs		1.237
Heat per *D. H. P.* per hour, and per minute, *B. T. U.* . .	14,382 ;	239.7
Steam per *D. H. P.* per hour, lbs		*12.864*
Fuel per *D. H. P.* per hour, lbs		1.364

Were these engines attached to boilers evaporating 10 lbs. instead of 9, the fuel-rate would be, per *I. H. P.*, 1.168 lbs., and per *D. H. P.*, 1.286, or about $1\frac{1}{6}$ and $1\frac{1}{4}$ lbs., respectively. The evaporation actually observed during the trials, was, as seen on the log, but 8.81 ; the apparent evaporation only 8.9, and the equivalent, "from and at 212," but 10.27 ; while the same figures for the coal, exclusive of its moisture, were, respectively, for apparent evaporation, 9.425 ; and, for equivalent, from and at the atmospheric boiling point, 10.72. Per pound of combustible, they become a tenth of a pound higher, 10.88.

The above given efficiency is 0.668, or two-thirds, that of a Carnot cycle working through the same range of temperatures and pressures. It is equal to $0.1873 \div 0.252 = 0.74$ of the thermodynamic efficiency for the Rankine cycle of the ideal case.

The purpose of the Director of Sibley College in promoting this investigation, and in securing all the aids that Sibley College and Cornell University, together with the officials of the City of Milwaukee and the constructing firm, could supply, was mainly to secure data permitting a careful comparison of the actual performance of the best results of application of the highest science and greatest skill of our time in the design, construction and operation of the contemporary steam-engine, with the computed and definitely known economy of the ideal, perfect, engine which may be taken as its representative under similar external conditions. It was intended thus to ascertain what margin still remains between the best contemporary practice and the limit set by thermodynamic principles for the perfect thermodynamic machine. This ascertained, the nature, extent, and method of reduction, of wastes may be readily learned, and their further reduction or elimination intelligently proceeded with. The outcome of the investigation was all that was anticipated, and resulted in showing, as above, that even the best known practice cannot as yet evade a waste of $11.678 - 9.23 = 2.45$ pounds steam per horse power, or above twenty per cent. of all the heat energy entering the system,

and that about ten per cent. of the energy thermodynamically transformed into indicated power is lost in friction within the machine.

The record now stands as related to indicated power, 217.6 *B. T. U.* per minute, 13,056 per hour, and 11.678 pounds of dry steam, at 125 pounds pressure, per horse-power per hour. The ideal engine, working in the same cycle, would demand, under similar external conditions, 42.42 *B. T. U.* per minute, 2545 per hour, or 9.23 pounds of steam per horse-power per hour. The difference, and the friction wastes—the difference between the indicated and the delivered, or the dynamometric horse power—are classed as the extra-thermodynamic and more or less controllable and avoidable wastes, the reduction of which, as well as the elevation of the thermodynamic ideal efficiency, constitute the standing duty of the designing and constructing engineer of our time.

These facts and principles are brought out in the paper presented by Dr. Thurston to the American Society of Mechanical Engineers at its last meeting, and of which an abstract only can be here given.

"The Maximum Contemporary Economy of the Steam-engine of the time has now so nearly approached the computed efficiency of its ideal, thermo-dynamic, representative, under similar external working conditions, that it has come to be admitted that the distance separating them, a consequence of the more or less unavoidable and irreducible wastes to which the former is subject and from which the latter is free, although still growing less, is exceedingly difficult of further reduction. The closer the approximation of the real to the ideal, the more difficult is it to further improve the machine, and the more certain is it that any considerable and rapid gain is out of the question. We have, for a century, been constantly changing the conditions exterior to the machine, in such manner as to raise the maximum efficiency of the ideal case as steadily higher and more difficult of attainment by the real engine; while we have as constantly and steadily reduced the defects of the latter in such manner as to make the approximation of the real to the ideal all the time closer, in spite of these obstructing circumstances."

. . . .

"With improving thermo-dynamic conditions and decreasing wastes in the engine, starting from the 5,000,000 duty of the

Savery engines still existing in the time of Watt, the 12,000,000 of Smeaton's Newcomen engine of the same period, and the first figures of Watt, perhaps averaging 20,000,000 foot-pounds per 100 pounds of fuel; and tracing the improvement through the most flourishing period of Watt's work, when he attained about 30,000,000, and his final perfection of the later Cornish engines, which, still later, attained in ordinary operation 60,000,000 to 80,000,000, we come to the period of successful introduction of the modern forms of the high-pressure multiple-expansion pumping engine, from 1860, giving duties ranging up to about 100,000,000 to 110,000,000, and to 130,000,000 in the succeeding generation and to date.

"The improving conditions which have made these results possible have been, first, the gradual elevation of the steam pressure from 5 lbs. per square inch in 1800 to 20 lbs. in 1840, to 50 at the middle of the century, 75 a quarter of a century later, to 120 and to 150 and 175 in contemporary stationary and marine practice, and even to above 15 atmospheres in some instances. The second, and no less essential element of this progress has been the simultaneous rise in the ratio of expansion from the time of Watt to the present, and from unity in his earliest practice to four for the latest Cornish form of the Watt engine, to six and eight a generation ago, and to fifteen and even twenty and more in the latest multiple-expansion machines. A terminal absolute pressure of about one-third of an atmosphere probably represents the limit to which expansion has been successfully carried. A higher rather than a lower terminal pressure is usual in the best practice of the day. The third element of improvement has been the increase of speed of piston and of rotation; although this has been less observable in steam pumping engines than in other types. Beginning with 200 to 300 feet per minute speed of piston, the figure has gradually risen to 500 and 600 in later years, and to above 1,000 in many cases to-day. These three have been the essential elements of improvement in the real engine; the latter supplementing the others, which give thermo-dynamic gain. Improvements in design and construction have completed the advances thus made practicable.

. . . .

"The history of the work is briefly as follows: the attention of the writer was first called to this remarkable case by Mr. E. D. Leavitt, who, in December, 1892, reported its performance as 12.17 lbs. of water per horse-power per hour, and sug-

gested obtaining from its designer and builders the facts relating to the plant, with a view to publication in the interests of science and the profession. Acting at once upon this suggestion, the writer secured permission from the City Engineer's office, and from the builders and the designers of the engine, to make a special duty-trial of the machine, in the interests of all concerned and of the profession especially. The trial was to be made by the Sibley College staff, as a part of the year's work of the Department of Experimental Engineering, with every facility that either the proprietors, the builders, or Cornell University and Sibley College could furnish. The results were to be worked up in the Sibley College laboratories, reported by the college to the designers, builders, and users of the engine, and published as soon as practicable by the writer, acting for the parties interested.

"It was proposed that the trial should be made during the Easter vacation of the college by a party to be selected, organized, and directed by Professor R. C. Carpenter, and to include such skilled and trained observers as could best be secured from his own department, re-enforced by observers sent in by the City Engineer and by the Allis Co. Among the "crew" sent out from Ithaca were several men engaged in graduate work, seeking material for their "Masters' theses," and some undergraduates who had enjoyed exceptional opportunities and shown great skill and efficiency in work of this kind. The special desire of the writer was to secure such data as would serve for a comparison of the theoretical ideal and the real engine, such as is here attempted; which comparison had never before been made in precisely this manner or with what it was hoped would prove such unexampled completeness.

"This trial was finally made as proposed, and the results proved to be even more striking and satisfactory than had been claimed by the builders or reported to the writer. The data and observations are preserved on the files of the Sibley College laboratory.*

. . . .

"The wastes of the steam engine are: (1) the thermo dynamic and unavoidable wastes due to the fact that, at the minimum limit of pressure, in the operation of the engine, a proportion of the heat-energy supplied, always considerable, and precisely determined by that limit, must inevitably be rejected from the system and lost to all thermo-dynamic use; (2) the wastes due to

*For all logs and data and a full description of the engine and its trial, see this journal for June, 1893.—[Editors.]

the conduction and radiation of heat from the exterior of the machine to surrounding bodies, with similar result ; (3) the internal wastes of conduction and transfer from steam to exhaust side without transformation into work ; (4) the wastes of dynamic energy by friction of the various rubbing surfaces of the engine. Of these the first is beyond remedy except by such reduction as may be possible by extension of the expansion to the limit of a terminal pressure coinciding with the back-pressure ; the second is controllable and largely reducible by suitably clothing the exterior of the engine with non-conducting materials ; the third is also reducible by reduction of the time permitted for the waste to take place and by making the working fluid and the surfaces exchanging heat with it of minimum conductivity and heat-storing power ; the fourth waste is only capable of reduction by the amount to which the friction of the machine may be reduced to minimum proportions as compared with the gross power developed. The first quantity has been brought down from an original value of 90 per cent. to 85, in many cases, possibly to 75 in some instances ; the second from 10, perhaps even 20, to 2 frequently, sometimes to less ; the third from 30 or 50 per cent., to, as in the present case, about 10 per cent., and the last waste has come down from 25 to 10 per cent., though usually in condensing engines ranging from 12 to 15.

Could steam be worked in the Carnot cycle, entering at maximum pressure, expanding adiabatically to minimum, rejecting heat with compression during the return-stroke until adiabatic compression could be made to restore it to its initial pressure and volume, thus converting only latent heat of expansion into work, and that to the full extent of the Carnot law $E = (T_1 - T_2) \div T_1$ there would be required only the following quantities per horse-power per hour :

STEAM DEMANDED : IDEAL CASE.

Engine condensing ; $p_2 = 1.5$; Complete Carnot Cycle.

Steam-pressure (abs.)	45	75	115	165	215	315
Efficiency	0.215	0.248	0.278	0.302	0.320	0.347
B. T. U. per horse-power per hr.	11,838	10,221	9,119	8,427	7,938	7,335

. . . .

"The difference between these figures and those computed for the somewhat different cycle actually and necessarily adopted, measures a waste due to imperfection of the thermo-dynamic cycle employed.

. . . .

"The ideal cycle taken as representative of the real cycle of the steam-engine, as customarily built and operated, assumes admission at boiler-pressure, adiabatic expansion to back-pressure, and then complete rejection of the charge from the system. The heat expended is seen to be, not the latent heat of vaporization, simply, but the sum of that quantity and the sensible heat required to raise the temperature of the feed-water from that at which it is supplied to the boiler to that at which it is converted into steam. The difference between this and the preceding Carnot cycle, and which is wasted in this case, even in the ideal engine, is the difference between the "total heat of evaporation" from the feed-water temperature and at the temperature of the boiler-steam, and the latent heat of vaporization, at the latter temperature.

"The wastes of the representative cycle of the real engine are thus exaggerated, as compared with the cycle of best effect, in consequence of the practical impossibility in our engines, as built, of raising the working fluid, then a mixture of steam and water, from the final pressure and temperature to the pressure and temperature of the initial stage, by mechanical compression; and this loss amounts to about 20 per cent. of the total heat of the steam, or to about 25 per cent. of the latent heat operating thermodynamically in the Carnot cycle, for pressures of 100 lbs., absolute, and a little over. It becomes an increasing percentage of waste as pressures rise, and, at 300 lbs. pressure, the Carnot cycle becomes nearly 40 per cent. more efficient than the representative ideal; the latter wasting in this manner about 30 per cent. of all the heat supplied and 40 per cent. of the quantity supplied the former. This measures the importance of finding a method of successfully employing the Carnot cycle in the steam-engine, a plan often sought, but, as yet, never found.

"The Representative Ideal Case most exactly paralleling the real case to be studied, is the following: *

"The thermo-dynamic Carnot Efficiency, for this case, is, as a maximum for the perfect ideal engine, $(T_1 - T_2) \div T_1 = 0.283$;

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* It may appear as interesting as it certainly is satisfactory to **know** that this case was computed, and the figures here given obtained, in advance of the trial with the results of which they are compared, and the estimated wastes were originally introduced as here given. The comparison of the estimates with the actual results of test are thus rendered somewhat striking. The computer was Mr. John R. Whittemore, M. M. E., at the time engaged in graduate work in Sibley College.

28.3 per cent. The case here studied is that of the jacketed engine, and it is assumed, with Rankine, that the jacket has precisely that effectiveness of action which insures the retention of the working charge in the dry and saturated state up to the point of rejection with the opening of the exhaust-valve. The formulas employed in these computations are those of Rankine, so far as applicable to the ideal case. The treatment of the wastes is that of the writer.*

"The data assumed are the following, and are as nearly those of the trial, as it was possible to make them, in advance.

DATA FOR COMPUTATIONS AND RESULTS.

$p_1 = 121.6 + 14.5 = 136.1$; $p_3 = 2.8$ lbs. per square inch; $T_1 = 811.8°$ F.

r	p_2	T_2	V_2	U	Therm. Efficiency.	Steam per H.P. per hour, W'.
15	7.68	642.2	48.93	206,600	0.232	9.61
20	5.55	628.0	66.40	214,600	.252	9.23
25	4.41	618.3	82.50	219,000	.258	9.02
30	3.63	610.5	98.90	220,380	.259	8.98
35	3.09	604.1	115.25	222,070	.261	8.92

"The wastes for these cases may be approximately computed, and, if added to the above expenditures, the sum will presumably be approximately the actual expenditure of the engine, always provided the design and construction to be so well and so intelligently carried out as to permit the operation of the machine to be representative of good contemporary practice. In the present case, there is not only no question of this fact; but we know that the performance of the real engine approximates more closely to the ideal than any case yet known. Our computations should, therefore, result in a larger, rather than a smaller, figure than is actually obtained for the expenditure of the engine during the trial.

"The two formulas most commonly employed by the writer in the computation of probable wastes by cylinder condensation, the most remarkable of those wastes which distinguish the real from the ideal case, are the following, in which W is the weight of steam condensed per hour, and W' that computed for the ideal case :

$$W = CA(T_1 - T_2)t; \quad W = (W'a\sqrt{rt}) \div D.$$

* For the Rankine equations, see either Rankin's *Steam-Engine and other Prime Movers*, or the writer's *Manual of the Steam-Engine*, vol I. For the treatment of the real, as distinguished from the ideal, case, see the latter, and especially Chaps. V and VI.

A and *a* are constants determined by experiment; *t* is the time of one stroke in seconds; and *D* is the diameter of the steam-cylinder in inches, *A* its internal superficies in feet.* As a matter of convenience, the second form was employed in checking results after test; but the first of these expressions was used in the antecedent computations; the temperatures being obtained on the assumption that the expansion was substantially the same in each cylinder. Taking the waste as being that of the cylinder most subject to this form of loss, and which our computations, as above, show to be, in this case, the low-pressure cylinder, we find, for $D = 74$; $r = 3$; computing for ideal steam and waste, respectively, $W' = 9.23$, as above, $W = 1.87$ lbs. of steam per *I.H.P.* per hour. The total loss by clearance spaces is 0.13 lbs.; that due to "drop" and intermediate losses of energy is 0.41, and the total is thus, neglecting external radiation, 11.64 lbs. of steam per indicated horse-power per hour. To this nearly 5 per cent. should be added, probably, for external wastes, and the total becomes 12.2 lbs. per *I.H.P.* per hour, thus: †

Taking the mechanical efficiency of the engine as 90 per cent., the expenditure of steam per dynamometric horse-power per hour, as computed, will be found to be 13.5 lbs. ‡

DISTRIBUTION OF ENERGIES.

ENERGY SUPPLIED.		STEAM PER HOUR.	
		Per I.H.P.	Per D.H.P.
Useful work	.230	2.80	3.10
Thermal wastes	.748	9.13	10.12
Dynamic wastes	.022	0.27	0.28
Total received	1.00	12.20	13.50

. . . .

"The quality of steam was high—98.95—a point which is very

* *Manual of the Steam-Engine*, Vol. I, Chap. VI.

† This figure would usually be nearer 2 per cent. on engines of this size, giving 11.86 and 13.2 lbs. as the better computed totals, almost exactly the actual quantities.—[R. H. T.]

‡ As has been seen, the actual figures were, with boilers working with slightly moist steam, 11,678 lbs. per *I.H.P.*, and 12.86 lbs. per *D.H.P.*; the engine working with slightly less thermal efficiency than computed, but more than compensating this defect by an exceptionally low friction waste. In the contractor's trial these figures become 12.155 lbs. steam per *I.H.P.*, and 13.51 lbs. per *D.H.P.*—very nearly identical with the computed figures. Substantial identity is also given in the case of the Chicago engine.

carefully provided for by the designer, and probably makes up in a very sensible degree for the low evaporation rate ; both having a common origin in the slow combustion of the fuel.

"The dry steam, the high pressure, the large expansion ratio, the low condenser pressure and temperature, the inappreciable air-leak into the condenser, the excellent valve-gear and well proportioned ports, the very unusually small clearances, combine to give us here the closest approximation to the ideal case that has yet been recorded. The indicator-diagrams, which have been elsewhere reproduced, correspond with extraordinary closeness to the ideal ; and the loss of work by discrepancy between the ideal and the real diagram is as remarkably small.—[JOURNAL, June, 1893.]

"The mean effective pressure for the engine, reduced to low-pressure cylinder volume, is 22 lbs.; each pound gained by improved vacuum is thus a gain of $1/22=0.0455$, or 4.55% in the work of the engine, of which a small percentage, again, must be returned in the operation of the air-pump. Four per cent. per pound of pressure, thus gained, is considered by the designers of the engine well worth all the care, skill and conscientious supervision of the operation of the engine required to obtain and to maintain it. The slight compression observed is made less effective by the low terminal pressure ; but it has a sensible effect in reducing the slight loss by clearance.

"The low friction loss of the engine is due to a number of concurrent circumstances.* The cylinders are vertical ; they are coupled, piston to piston, with the pumps ; the wheel and shaft have only the friction of their own weight and of the small, varying work of regulation ; the triple crank arrangement makes regulating easy and shaft friction a minimum ; the circulating pump works in a solid column, demanding very little power in its movement ; the stuffing-boxes are deep, and thus need be but lightly packed ; and the whole machine is designed, constructed, and operated with evident regard to the relative magnitude and importance of the partially avoidable wastes, both dynamic and

*The friction of the engine is remarkably low for this type of pumping engine ; but it is, of course, still above the figure obtained from the best direct-acting machines, which, in the Newton, Mass., trial, reported recently, for example, was found to be 4.2 per cent., giving a mechanical efficiency of 0.958, as compared with that here obtained of 0.9078. But the latter figure excels, on the other hand, probably, that obtained from the average direct-acting machine.

thermal, of the whole machine. Perhaps one of the most interesting of the minor points noted in the whole investigation is the gradual reduction, with time, of the dynamic waste; the friction falling from about 14% on starting the new engine and at the contractor's, the Benzenberg and Lewis, trial, to 9% at the Sibley College trial, eight months later.

"The distribution of energy supplied the engine, during the trial, can now be readily determined by comparison of the real with the ideal case. It is seen by reverting to the estimates already given, that the ideal engine, under similar circumstances, would have an efficiency of about 0.25, and would require 9.25 lbs. of steam, nearly a pound of fuel, per horse-power per hour. We find, from the records of the trial, that of all the energy developed in the cylinders, 9.22 per cent. was wasted in friction. We thus obtain the following figures to compare with those computed, p.:

DISTRIBUTION OF ENERGIES.

PART OF TOTAL ENERGY SUPPLIED.	Per ct.	Per D.H.P. per Hour.	
		B. T. U.	Lbs. st.
Thermal and thermo-dynamic wastes . . .	81.27	11688.25	10.455
Dynamic, or friction, wastes	1.73	248.81	0.222
Useful work	17.00	2444.94	2.187
Total thermo-dynamic transformation . . .	18.73	2693.75	2.409
Total from boilers	100.00	14,382	12.864

"Of the total heat-wastes, amounting to above 80 per cent., we have seen that 100—27=73 per cent. is the unavoidable thermo-dynamic waste that even the Carnot cycle cannot evade. The difference, 81.27 — (100 — 18.73= 71.27)= 10 per cent., is traceable to "cylinder condensation" and external conduction and other defects. This is a condensation of 1.19 lbs. of steam per D. H. P. per hour, or 10 per cent. of the consumption of steam per I. H. P. per hour. The figure computed was 1.87 lbs. or 50 per cent. higher; and this fact indicates that the jackets, though not operating as assumed in the case of the Rankine cycle, were remarkably effective. They very nearly supply just the amount of heat required, were there no thermo-dynamic condensation, to retain the working charge in the dry and saturated condition throughout the stroke. The dry steam supplied, and the effective action of the jackets are thus probably very influential in the production of the exceptional economy here observed. But initial condensation is here considerable, ranging from 20 per

cent. in the high, to 25 per cent. in the low pressure cylinder, at cut-off; and, besides, 73 per cent. remains a thermo-dynamic waste which we are as yet unable to even surmise possible methods of conquering.

. . . .

"'The fundamental principles of the multiple-expansion engine are closely observed in the design of this machine. The low cylinder-condensation shows not only that the jackets were well-designed and efficient, but that the wastes of the high-pressure and intermediate cylinders do not flood the low-pressure cylinder and produce unnecessary loss. The distribution of power among the several cylinders is excellent; the high-pressure and intermediate having substantially equal powers, and the low-pressure owing its higher power to the addition of the full stroke accession of effort due to its communication with the condenser.

"The total ratio of expansion was very nearly 20 in this case, and the ratio for each, assuming equality, was thus $\sqrt[3]{19.205} = 2.7$ the apparent cut-off being variable between 0.32 and 0.39. The terminal pressure is also here exceptionally low; the usual best figure being considered to be, with good engines, not below 6 lbs. absolute; it is more commonly 8, and often 10. Here it is made as low as 5.3, and the back-pressure is but 1.63 lbs., or 0.11 atmosphere; the drop between cylinder and condenser being unusually slight.

"Jacket Action is here fairly effective. The measurements of the indicator diagrams, as originally practiced by Hirn, show a progressive increase, in the internal condensation, of from 20 per cent. in the first and in the intermediate cylinder, to 25 per cent. in the low pressure cylinder. The difference between the initial and the final condensation is $25 - 20 = 5$ per cent., or about one-third the thermo-dynamic condensation; this indicating that "cylinder condensation," finally amounted to about 10 per cent., in spite of the effectiveness of the jackets. If we take the waste from external distribution of heat to be 5 per cent., and the condensation in the jacket to be due to internal absorption of heat to the extent of 4.25 per cent., it would appear that the heat expended in the jackets was at least twice as effective—perhaps in much larger proportion, the exact amount is indeterminable—as that worked in the steam cylinders. The observed condensation increases 2 per cent., cylinder by cylinder; the normal thermo-dynamic, or adiabatic, condensation would be 5 per cent., similarly cumulative; and the actual initial cylinder condensation is found

to be 20 per cent. It thus appears that the jackets reduced the latter quantity, which, in an unjacketed engine of this size and action, would, as known by experience, be at least 25 per cent., and possibly 30, to 20 per cent. initially, and to a final—which would have been 30 or 40—of 25. This heat-transfer from the jackets is equivalent to a superheating of about 100° F. They thus saved, net, not less than 10 per cent. This, taken as a fraction of the $16,410 reported by the officers of the city water department as the annual cost, amounts to $1,641, the interest on $32,820, and on probably ten times the actual increased cost of engines due to jackets; otherwise stated, it is probably 50 per cent. interest on the investment in jackets.

"The quality of steam supplied by the boiler being taken at 0.98 at the engine, 0.80, 0.80, and 0.74, respectively, in the several cylinders taken in order, the initial condensation is seen to have been 18 per cent. in the first, 18 per cent. in the second, and 24 per cent. in the third cylinder, assuming, as seems to have been at least approximately the fact, that the jackets were able to barely compensate the progressive deterioration of quality in the engine due to thermo-dynamic condensation of steam. The jackets therefore reduced the cylinder condensation due to the action of the sides of the cylinders from what would probably have been 30, perhaps 40, per cent. of the total supplied, by holding the quality of the working steam up to approximately 0.80 at entrance into each cylinder.

"The tables appended, containing the results of the application of Hirn's Analysis to this case, and representing the first complete analysis yet made of a commercial machine of this character, have double interest in the fact that they exhibit so fully the conditions affecting the flow of energy through the engine, and its distribution into useful and wasted work, and at the same time are representatative of this distribution as affected by the best of contemporary designing, and as attaching to the most successful instance on record, to date, of thermo-dynamic transformation in commercial, or other, applications.*

"The analysis is so complete that no difficulty will be experi-

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* The computations of which the data and results are here published were made for the writer, in this instance, by Messrs. S. H. Barraclough (B. E., Univ. Sydney, N. S. W.) and L. S. Marks (B. S., Mason Coll. and Lond. Univ., G. B.), graduate students engaged in two years' advanced work and research, preparatory to taking the higher degree in engineering in Sibley College, Cornell University.

enced in tracing out the source of the derangement of the usual process of analysis.

"The tables exhibit the whole course of the received, the distributed, and the applied and rejected energies, in each cylinder, and from cylinder to cylinder, up to their final discharge, into the condenser and the air, so far as rejected.

"The heat rejected from the first and second cylinders was in each case taken as the heat received, as obtained from the indicator-diagram, less the work performed plus the radiation. That rejected from the low-pressure cylinder was obtained from a special supplementary trial, as already noted.

"The main points of interest, in addition to those already observed, and connoted with the latter, are the following :

"Steam entered the engine nearly dry, having a quality 0.9895, dry steam being taken as unity ; 5.56 lbs. being expended per revolution, in addition to the 0.0402 lbs engaged in the clearance-space, which latter, however, was extraordinarily small, 1.4 per cent. At 20.3133 revolution per minute, this developed 573.87 I. H. P.

"The steam used per 100 strokes is taken, and we find that of the 556.4 lbs. sent to the engine from the boiler, 504.5 actually enter the cylinders and pass through them to the condenser ; receiving heat, meantime, from the 52 lbs. of jacket steam, 9¼ per cent. of the total steam supplied, which is condensed in the jackets to supply that heat. The engine receives 598,800 B. T. U. with the steam entering it, and 40,870 from its jackets, a total of 639,670 B. T. U. Of this, 119,652 B. T. U. is transformed into work and the remainder wasted. Of this remainder, 6,598 units are radiated from the exterior of the engine. The jackets supply 13,350 to 14,150 B. T. U. to each cylinder, the quantity increasing, as would be anticipated, with fall of temperatures and pressures.

"The quality of the entering steam is 98.95 per cent., which becomes 86.77 at cut-off by the initial condensation of 12.18 per cent. by the chilling action of the cylinder walls. Reëvaporation and the heat from the jacket conspire to raise these figures to 93.3 at release, and to 96.8 during exhaust from the high-pressure cylinder. At cut-off in the intermediate cylinder, this drops to 85.4 again ; the jackets compensating the thermodynamic, adiabatic condensation very nearly, and the defect of quality, as compared with the steam in the high-pressure cylinder, being produced substantially by external wastes. At release, the quality becomes

the same as at the same point in the first cylinder; the jackets having, by this time, compensated the external wastes as well In the low-pressure cylinder the quality 94 at entrance becomes 81 at cut-off, external wastes having apparently somewhat larger influence than previously, and thermodynamic condensation showing very much more of its cumulative effect. The steam sent to the condenser, finally, has a quality of 89.95 per cent., showing clearly the result of the opposing actions of jacket heat and thermodynamic and thermal wastes and condensations. The negatives values, in each table, show that each cylinder, on the whole, gains more than it loses—those quantities representing heat transferred to the working charge—and the magnitudes of the quantities of heat entering from the jackets during expansion and exhaust are seen to be amply sufficient to account for the jacket effect observed in the final efficiency.

"In the tables, line 9 gives the quantity of heat supplied the engine in the steam entering the working cylinder, and the three shuts show its gradual variation as it passes through, losing energy in thermal form by external wastes and in dynamic form by conversion into work. In each case, as seen on lines 23, 24, more heat enters than leaves the cylinder, the gain being due jacket action and amounting to about two per cent., net. The reëvaporations in the cycle, subsequent to cut-off, and accessions of heat from the jackets, lines 19, 20, are greater, as a total, during expansion than during exhaust in the high-pressure cylinder, while this relation is reversed in the intermediate and large cylinders, showing the greater probable advantage of jacketing the former in cases similar to that here studied. This gain during exhaust is wholly a waste; it is in part only a gain during expansion. The jacket is evidently only valuable by its effective restriction of initial condensation. Its action is wholly unsatisfactory during the whole cycle otherwise, for even the heat added by it during expansion is thermodynamically undesirable. It would be better if it were received direct from the boiler and at the maximum temperature of the prime steam. The fact of an excess of heat being rejected from the cylinder is only satisfactory as an evidence that the cylinder walls are dry, and presumably, also, warmed by the jacket, which latter fact is shown by the extent to which thermal interior waste is reduced in this engine. The exceptionally low total of wastes, corresponding to two and a half pounds of steam, or less than 30 per cent. of the computed demand of the ideal engine, and which represents the remaining

Hirn's Analysis—Data and Results per 100 Revolutions. High Pressure Cylinder (Jacket Steam Excluded) with First Receiver.

Quantities.	Symb.	Formulæ.	
1. Steam from boiler entering working cyl., lbs.	M	. . . .	504.5
2. Steam in clearance, lbs.	M_c	$100\,(V_c \div C_c X_c)$	18.158
3. Steam at admission, lbs.	M_o	$100\,(V_c + V_o \div v_o)$	. . . . .
4. Steam used by calorim., lbs.	. . .	. . . .	. . . . .
5. Steam, total, lbs.	$M + M_o$	. . . .	522.658
6. Heat of condensed steam	K'	Mq_g	. . . . .
7. Condensed water, lbs.	G	. . . .	. . . . .
8. Heat given to cond'ng water	K	$G\,(qk - ql)$ (Heat rejected)	573,505
9. Heat supplied to engine	Q	$M\,(xr + q)$	598,800
10. Sensible heat at admission	H_o	$M_o q_o$	5,819
11. Internal heat at admission	H_o'	$100\,\frac{V_c + V_o}{v_o}\,\rho_o$	14,270
12. Sensible heat at cut-off	H_1	$(M + M_o)\,q_1$	167,400
13. Internal heat at cut-off	H_1'	$100\,\frac{V_c + V_1}{v_1}\,\rho_1$	356,900
14. Sensible heat at release	H_2	$(M + M_o)\,q_2$	128,700
15. Internal heat at release	H_2'	$100\,\frac{V_c + V_2}{v_2}\,\rho_2$	411,300
16. Sensible heat, beg. of comp.	H_3	$M_o q_3$	4,527
17. Internal heat, beg. of comp.	H_3'	$100\,\frac{V_c + V}{v_3}\,\rho_3$	15,700
18. Cyl. loss during admission	Q_a	$Q + H_o + H_o' - H_1 - H_1' - AW_a$	+62,629
19. Cyl. loss during expansion	Q_b	$H_1 + H_1' - H_2 - H_2' - AW_b$	—46,990
20. Cyl. loss during exhaust	Q_c	$H_2 + H_2' - H_3 - H_3' - K - K' - AW_c$	—27,862
21. Cyl. loss during compress'n	Q_d	$H_3 + H_3' - H_o - H_o' - AW_d$	—1,064
22. Heat discharged, and work	B	$K + K' + AW$	609,961
23. Loss*	D	$Q - B$	—11,161
24. Loss*	D'	$Q_a + Q_b + Q_c + Q_d$	—11,161
25. Quality of steam entering	x	per calorimeter . . . . . . per cent.	98.95
26. Quality of steam at cut-off	x_1	$100\,\frac{V_c + V_1}{(M + M_o)\,v_1}$ "	86.77
27. Quality of steam at release	x_2	$100\,\frac{V_c + V_2}{(M + M_o)\,v_2}$ "	93.3
28. Quality of steam at comp.	. . .	$100\,\frac{V_c + V_3}{M_o v_3}$ "	. . . . .
29. Quality of steam at admis'n	x_o	per calorimeter "	. . . . .
30. Quality of steam at exhaust	x_5	$\left(\frac{K + K'}{M - M_x} - q_5\right) \div r_5$ "	96.8
31. Heat lost, admission	a	$Q_a \div Q$ "	10.46
32. Heat restored, expansion	b	$Q_b \div Q$ "	—7.86
33. Heat rejected, exhaust	c	$Q_c \div Q$ "	—4.65
34. Heat lost, compression	d	$Q_d \div Q$ "	.18
35. Heat utilized, work	w	$\frac{W}{778} \div Q$ "	6.087
36. Heat lost, radiation	R	radiation $\div Q$ "	0.367
37. Ratio, radiation to work	. . .	$R \div w$	.0603
38. Ratio, cyl. cond. to work	. . .	$a \div w$	1.72
39. Thermodynamic efficiency	E	$(t - t_3) \div (460 + t)$ . . . . per cent.	8.96
40. Actual efficiency	E_1	$AW \div Q$ "	6.087
41. Effi'y compared with ideal	E'	$E_1 \div E$ "	68.0
42. Radiating surface of engine	S	To be measured "	. . . . .
43. Loss per sq. foot per hour	F	$R \div S$ (time of run, hours B. T. U.)	. . . . .
44. Loss per deg. difference temp	. . .	$F \div (t' - t'')$	. . . . .

Special symbols V_c = volume clearance, t = measured temperature. Subscript 5 applies to exhaust, i to injection, k to discharge, g to air-pump discharge. $A = \frac{1}{778}$.

Correct for steam used by Calorimeter, when necessary.

* This quantity is the difference between the heat loss by radiation and that received from the jacket. The negative sign shows that more heat is received than lost.

HIRN'S ANALYSIS—DATA AND RESULTS FOR 100 REVOLUTIONS—INTERMEDIATE CYLINDER (JACKET STEAM EXCLUDED) WITH SECOND RECEIVER.

QUANTITIES.	SYMB.	FORMULÆ.	
1. Steam entering cyl., lbs.	M	. . . .	504.5
2. Steam at admission, lbs.	M_0	$100\,(V_c + V_0) \div v_0$	22.33
3. Steam used by calorim., lbs.	. . .	. . . .	. . . . .
4. Steam, total, lbs.	$M+M_0$	. . . .	526.83
5. Heat of condensed steam	K'	Mq_g	. . . . .
6. Heat rejected	G	. . . .	549,380
7. Heat given to cond'g water	K	$G\,(qk - qi)$	. . . . .
8. Heat supplied to engine	Q	$M(xr + q)$	573,505
9. Sensible heat at admission	H_0	$M_0 q_0$	5,534
10. Internal heat at admission	H_0'	$100 \dfrac{V_c + V_0}{v_0} \rho_0$	18,780
11. Sensible heat at cut-off	H_1	$(M + M_0) q_1$	125,600
12. Internal heat at cut-off	H_1'	$100 \dfrac{V_c + V_1}{v_1} \rho_1$	381,400
13. Sensible heat at release	H_2	$(M + M_0) q_2$	95,400
14. Internal heat at release	H_2'	$100 \dfrac{V_c + V_2}{v_2} \rho_2$	434,100
15. Sensible heat, beg. of comp.	H_3	$M_0 q_3$	4,201
16. Internal heat, beg. of comp.	H_3'	$100 \dfrac{V_c + V_3}{v_3} \rho_3$	18,420
17. Cyl. loss during admission	Q_a	$Q + H_0 + H_0' - H_1 - H_1' - AW_a$	67,439
18. Cyl. loss during expansion	Q_b	$H_1 + H_1' - H_2 - H_2' - AW_b$	—35,755
19. Cyl. loss during exhaust	Q_c	$H_2 + H_2' - H_3 - H_3' - K - K' - AW_c$	—41,465
20. Cyl. loss during compress'n	Q_d	$H_3 + H_3' - H_0 - H_0' - AW_d$	—1,380
21. Heat discharged, and work	B	$K + K' + AW$	584,666
22. Loss*	D	$Q - B$	—11,161
23. Loss*	D'	$Q_a + Q_b + Q_c + Q_d$	—11,161
24. Quality of steam entering	x	per calorimeter . . . . . . per cent.	. . . . .
25. Quality of steam at cut-off	x_1	$100 \dfrac{V_c + V_1}{(M + M_0) v_1}$ "	85.4
26. Quality of steam at release	x_2	$100 \dfrac{V_c + V_2}{(M + M_0) v_2}$ "	93.2
27. Quality of steam at comp'n	. . .	$100 \dfrac{V_c + V_3}{M_0 v_3}$ "	. . . . .
28. Quality of steam at admiss'n	x_0	per calorimeter "	. . . . .
29. Quality of steam in exhaust	x_5	$\left(\dfrac{K + K'}{M - M_x} - q_5\right) \div r_5$ "	94.0
30. Heat lost, admission	a	$Q_a \div Q$ "	11.75
31. Heat restored, expansion	b	$Q_b \div Q$ "	—6.23
32. Heat rejected, exhaust	c	$Q_c \div Q$ "	—7.23
33. Heat lost, compression	d	$Q_d \div Q$ "	—0.24
34. Heat utilized, work	w	$\dfrac{W}{778} \div Q$ "	6.155
35. Heat lost, radiation	R	Radiation $\div Q$ "	.384
36. Ratio, radiation to work	. . .	$R \div w$	.0623
37. Ratio, cyl. cond. to work	. . .	$a \div w$	1.795
38. Thermodynamic efficiency	E	$(t - t_3) \div (460 + t)$ . . . . per cent.	8.99
39. Actual efficiency	E_1	$AW \div Q$ "	6.155
40. Effic'y compared with ideal	E'	$E_1 \div E$ "	68.55
41. Radiating surface of engine	S	To be measured	. . . . .
42. Loss per sq. foot per hour	F	$R \div S$ (time of run, hours B. T. U.)	. . . . .
43. Loss per deg. difference temp	. . .	$F \div (t' - t'')$	. . . . .

Special symbols, V_c = volume clearance, t = measured temperature. Subscript 5 applies to exhaust, i to injection, k to discharge, g to air-pump discharge. $A = \frac{1}{778}$.

Correct for steam used by calorimeter, when necessary.

* Same explanation as for high-pressure cylinder. Radiation assumed equal for all three cylinders, and heat received from jackets assumed equal in high and intermediate pressure cylinders.

HIRN'S ANALYSIS—DATA AND RESULTS PER 100 REVOLUTIONS—LOW-PRESSURE CYLINDER (JACKET STEAM EXCLUDED).

QUANTITIES.	SYMB.	FORMULÆ.	
1. Steam ent. work'g cyl., lbs.	M	. . . .	504.5
2. Steam at admission, lbs.	M_0	$100\,(V_c + V_0) \div v_0$	9.61
3. Steam used by calorim., lbs.		. . . .	. . . . .
4. Steam, total, lbs.	$M+M_0$	. . .	514.11
5. Heat of condensed steam	K'	Mq_g	38,920
6. Condensed water, lbs.	G	. . . .	8,184
7. Heat given to cond'g water	K	$G\,(qk - qi)$	474,500
8. Heat supplied to engine	Q	$M\,(xr + q)$	549,380
9. Sensible heat at admission	H_0	$M_0 q_0$	1,746
10. Internal heat at admission	H_0'	$100\,\frac{V_c + V_0}{v_0}\,\rho_0$	8,590
11. Sensible heat at cut-off	H_1	$(M + M_0)\,q_1$	93,450
12. Internal heat at cut-off	H_1'	$100\,\frac{V_c + V_1}{v_1}\,\rho_1$	353,600
13. Sensible heat at release	H_2	$(M + M_0)\,q_2$	68,300
14. Internal heat at release	H_2'	$100\,\frac{V_c + V_2}{v_2}\,\rho_2$	399,800
15. Sensible heat, beg. of comp.	H_3	$M_0 q_3$	824.2
16. Internal heat, beg. of comp.	H_3'	$100\,\frac{V_c + V_3}{v_3}\,\rho_3$	3,594
17. Cyl. loss during admission	Q_a	$Q+H_0+H_0'-H_1-H_1'-AW_a$	11,307
18. Cyl. loss during expansion	Q_b	$H_1+H_1'-H_2-H_2'-AW_b$	464
19. Cyl. loss during exhaust	Q_c	$H_2+H_2'-H_3-H_3'-K-K'-AW_c$	−116,818.2
20. Cyl. loss during compress'n	Q_d	$H_3+H_3'-H_0-H_0'-AW_d$	−6,902.8
21. Heat discharged, and work	B	$K+K'+AW$	561,330
22. Loss*	D	$Q-B$	−11,950
23. Loss*	D'	$Q_a+Q_b+Q_c+Q_d$	−11,950
24. Quality of steam entering	x	per calorimeter . . . . . . per cent.	. . . . .
25. Quality of steam at cut-off	x_1	$100\,\frac{V_c + V_1}{(M + M_0)\,v_1}$ . . . . . "	81.15
26. Quality of steam at release	x_2	$100\,\frac{V_c + V_2}{(M + M_0)\,v_2}$ . . . . . "	83.33
27. Quality of steam at comp'n	. . .	$100\,\frac{V_c + V_3}{M_0 v_3}$ . . . . "	. . . . .
28. Quality of steam at admiss'n	x_0	per calorimeter . . . . . . "	. . . . .
29. Quality of steam in exhaust	x_5	$\left(\frac{K + K'}{M - M_x} - q_5\right) \div r_5$ . . . "	89.95
30. Heat lost, admission	a	$Q_a \div Q$ . . . . "	2.056
31. Heat restored, expansion	b	$Q_b \div Q$ . . . . "	.084
32. Heat rejected, exhaust	c	$Q_c \div Q$ . . . . "	−21.22
33. Heat lost, compression	d	$Q_d \div Q$ . . . . "	−1.256
34. Heat utilized, work	w	$\frac{W}{778} \div Q$ . . . . "	8.7
35. Heat lost, radiation	R	Radiation $\div Q$ . . . . . . "	.40
36. Ratio, radiation to work	. . .	$R \div w$	.046
37. Ratio, cyl. cond'n to work	. . .	$a \div w$	.236
38. Thermodynamic efficiency	E	$(t - t_3) \div (460 + t)$ . . . . per cent.	10.98
39. Actual efficiency	E_1	$AW \div Q$ . . . . "	8.70
40. Effi'cy compared with ideal	E'	$E_1 \div E$ . . . . "	79.18
41. Radiating surface of engine	S	To be measured	. . . . .
42. Loss per sq. foot per hour	F	$R \div S$ (time of run, hours B. T. U.)	. . . . .
43. Loss per deg. difference temp	. . .	$F \div (t' - t'')$	. . . . .

Special symbols, V_c = volume clearance, t = measured temperature. Subscript 5 applies to exhaust, i to injection, k to discharge, g to air-pump discharge. $A = \frac{1}{778}$.

Correct for steam used by calorimeter, when necessary.

* Same explanation as for high-pressure cylinder.

margin for gain in future constructions, is largely due to this effective phase of jacket action.

"It is to be noted that the reduced pressure in the low-pressure jacket makes the relative heat supply vary somewhat peculiarly. The high and intermediate cylinders were jacketed, like the receivers, with boiler steam. In the low pressure jacket the pressure was reduced to 34 lbs. by gauge.

"The engine, as a whole, has 65 per cent. of the efficiency of the ideal thermo dynamic machine. The thermo-dynamic efficiency of the machine, as a whole, was 28.94 per cent., and its actual efficiency 18.58, all thermal losses included. This is a wonderful result, and the designer, the builders, and the proprietors of this extraordinary engine are entitled to congratulation, not only for such great success, but for having thus shown what can be done by good designing, good construction, and good management, by the most intimate union of scientific and practical wisdom and art, toward the perfection of the steam-engine, in the approximation of the real to the ideal."

APPENDIX.

COMPUTATION OF RADIATION LOSSES AND HEAT REJECTED FROM EACH CYLINDER PER 100 REVOLUTIONS.

Total heat admitted to high-pressure cylinder	598,800	B. T. U.
Total heat used in all jackets, assuming 1-3 weight of jacket steam to be used in each jacket	40,870	"
Total heat used	639,670	"
Heat rejected from low-pressure cylinder	513,420	"
Total work done	119,652	"
Total radiation loss	6,598	"
	639,670	"
Radiation loss from each cylinder assumed to be equal in all cylinders	2,199	"

Heat rejected from high-pressure cylinder = heat entering + heat supplied by jacket — radiation loss — work done

$$= 598{,}800 + 13{,}360 - 2{,}199 - 36{,}456$$
$$= 573{,}505 \text{ B. T. U.}$$

Heat rejected from intermediate-pressure cylinder = heat rejected from high-pressure cylinder + heat supplied by jacket — radiation loss — work done

$$= 573{,}505 + 13{,}360 - 2{,}199 - 35{,}286$$
$$= 549{,}380 \text{ B. T. U.}$$

Heat rejected from low-pressure cylinder = heat rejected from intermediate-pressure cylinder + heat supplied by jacket — radiation loss — work done

$$= 549{,}380 + 14{,}150 - 2{,}200 - 47{,}910$$
$$= 513{,}420 \text{ B. T. U.}$$
$$= K + K' \text{ (see low-pressure analysis).}$$

KAPP'S ALTERNATE CURRENT PROBLEMS.

BY HARRIS J. RYAN.

The six hundred and fifty-eighth number of the *London Electrician* published an instructive set of alternate current problems for circuits possessing resistance, self-induction, and capacity. Mr. Gisbert Kapp is the author of the problems and their graphic solutions. They were put forth by him as a brief commentary on the alternate current effects met with in the practice of the London Electricity Supply Corporation. This company has a plant of 10,000 volt alternators at Depford, seven miles from the heart of London, over which distance the current is conveyed by means of concentric cables. Owing to the capacity of these cables and the self-induction produced by magnetic leakage in the transformers, some remarkable results were obtained that had not been anticipated by the engineers of the company, attempting to supply current at a pressure of 10,000 volts through concentric cables. As a study of the elements involved in the production of results like those observed in the Depford plant Mr. Kapp contributed the problems contained herein. The original article is terse, and at the time was intended only for engineers well up in alternate current work. A number of engraver's errors existed in the original figures. The

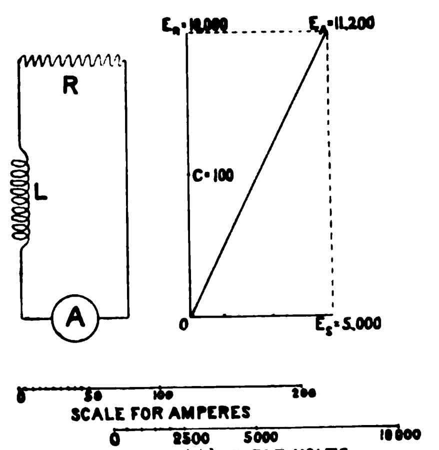


FIG. 1. FIG. 2.

errors have been corrected in the figures here given, and the text expanded for the purposes of the student. While these problems

are set with high pressure values, the methods employed are just as useful for conditions involving the use of low pressures. Mr. Kapp has always called the ordinary sine function diagrams, "clock-face" diagrams, and reckons time in a clock-wise direction instead of anti-clock-wise, as is the more common method.

Figure 1 gives a diagram of the circuit. An alternator *A* furnishes current at a periodicity of 80 and a pressure of 10,000 volts through a circuit having a resistance of 100 ohms and a coefficient of self-induction of .100 henrys. It is desired to know what current will be established through this circuit. The solution is made by first determining the relation between the impressed *E.M.F.*, fall of potential due to ohmic resistance, and the *E.M.F.* of self-induction. To do this we will assume some current to have been established through the circuit. For this purpose almost any value of current would answer. In general, though, it is wise to select the current which would be established if self-induction were not present. Such a current in this case would be 100 amperes. The *E.M.F.* required to send 100 amperes through 100 ohms equals 10,000 volts. Consequently E_r or the fall of potential for this current equals 10,000 volts. The self-induction *E.M.F.*, E_s will equal the product of C, L, 2π and $\frown\smile$, or

$$E_s = 100 \times .1 \times 2\pi \times 80 = 5000 \text{ volts.}$$

The electrical pressure that compensates for self-induction *E.M.F.* is always 90 degrees in advance of the current that produces such self-induction *E.M.F.* The *E.M.F.'s* due to fall of potential and self-induction are drawn accordingly in figure 2, and the resultant of the parallelogram that they form equals 11,200 volts. This is the impressed *E.M.F.* that the alternator would have to produce to send 100 amperes through the circuit under consideration, and the desired relation between the impressed self-induction, and fall of potential *E.M.F.'s* has been established. It now remains to determine the current that would be established when the alternator furnishes 10,000 volts instead of 11,200. If we diminish E_a in the ratio of $10{,}000 \div 11{,}200$ the remaining elements of the figure will diminish in the same proportion. Accordingly the actual current that would be established is

$$C = 100 \times 10{,}000. \div 11{,}200 = 89.2 \text{ amperes.}$$

For far smaller *E. M. F.'s* such as are met with in incandescent lighting these same relations exist. The reader should note that although 10,000 volts are needed to send 100 amperes through a

resistance of 100 ohms, and 5,000 volts to set up this current through that part of the circuit that possesses no resistance, but a self-induction of one tenth henry, only 11,200 volts were necessary for the combined purpose. For example electric metres of such types as are generally used on 50 volt alternate current incandescent lighting circuits contain coils through which the lamp current passes, that possess considerable self-induction. When lamps are supplied through these metres to their full capacity the measured difference of potential between their terminals in many cases is found to be from five to ten volts. Now the fall of potential through the metres due to the ohmic resistance is very small so that practically all of the potential difference is due to the *E. M. F.* of self-induction. Yet this difference of potential, large as it is around the meter, does not change the resultant pressure upon the lamps by more than a small fraction of a volt, owing to the relation that exists between the *E. M. F.'s* as brought out in the above problem.

Two problems are given in connection with the circuit represented in Fig. 3. The first is solved in Fig. 4, and the second

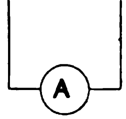


FIG. 3.

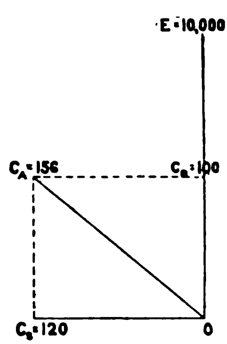


FIG. 4.

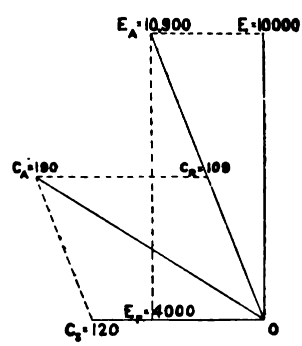


FIG. 5.

in Fig. 5. In these problems we are concerned with one circuit possessing self-induction in parallel with one that is non-inductive. In the first, see Fig. 4, we have the pressure of a generator given as 10,000 volts, the self-induction at L equals .166 henrys, the resistance at R equal 100 ohms, and at r equal 0. The combined current that the machine will furnish to the two circuits is desired. It is evident at once that the current that will be be established through R is 100 amperes. The current that will be established through L is obtained from this equation that ex-

presses the relation between current and the self-induction *E. M. F.* that it produces :

$$C = \frac{E}{L\, 2\pi \sim}, \quad \text{or by substitution}$$

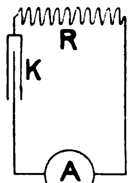
$$C = \frac{10{,}000}{.166 \times 2\pi \times 80} = 120. \text{ amperes.}$$

The current of 120 amperes through the self-induction circuit will be one-quarter period in advance of the *E.M.F.* that it produces and one-quarter period, therefore, behind the impressed *E.M.F.* of the machine. The 100 amperes through R will be in unison with the impressed *E.M.F.* of the machine. These values are given corresponding positions in Fig. 4. The diagonal of the parallelogram that they form is the desired resultant current, and is found to be 156 amperes.

In the second problem for the circuit of Fig. 3 r equals 33.4, R equals 100, L equals .166, and E equals 10,000, while the resultant current that the alternator will set up through the two circuits is desired as before. As in the problems of Fig. 2, it will first be necessary to locate the positions of the various values, then determine the resultant current at the pressure of the machine by the method of proportion. For this purpose 120 amperes are taken as the current through r L. We already know that this current will produce 10,000 volts in L while in r it will produce a fall of potential equal to $33.44 \times 120 = 4000$.

The *E. M. F.* necessary to compensate for this fall of potential is in unison and of the same sign as the current of 120 amperes. The diagram indicates the position of the 10,000 volts necessary to set up the 120 amperes through L and the 4,000 volts necessary for the same current through r. The resultant value is the diagonal of the parallelogram which they form, or E_a equals 10,900 volts. This, then, is the relative position of the pressure that the machine furnishes when establishing curent through rL. The current that will be established through R will be in unison with the resultant E_a and in amount will be $10{,}900 \div 100 = 109$ amperes. Giving this current a corresponding position in the diagram, we may now combine the current through rL and R and obtain the resultant. As is seen in figure 5, the diagonal of this parallelogram gives the value as 190 amperes. If we diminish E_a from 10,900 to 10,000, all other quantities will diminish in the same ratio. The resultant current, then, that the alternator would furnish through the two circuits at a pressure of 10,000 volts would be $C_a = 190 \times 10{,}000 \div 10{,}900 = 175$ amperes.

One problem is given for the circuit in Fig. 6. The alternator A furnishes current through a circuit made up of a condenser K in series with a non-inductive resistance R. $K = 5$ microfarads, $R = 100$ ohms. It is desired to know what current will be established by the machine through the circuit at a pressure of



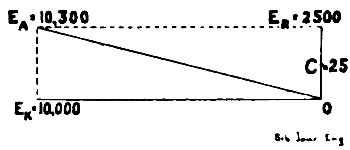


FIG. 6. FIG. 7.

10,000 volts. As before, the relation of the $E. M. F.$'s must first be established. For this purpose we will assume a current of 25 amperes to have been established through the circuit. The relation between capacity $E. M. F.$ and the current which produces it is given in the following equation: $C_k = 2\pi \sim K E_k \times 10^{-6}$ for microfarads. We have then

$$E_k = \frac{25 \times 10^6}{2\pi \times 80 \times 5} = 10{,}000 \text{ volts.}$$

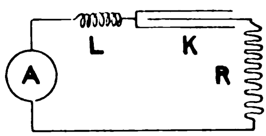
The fall of potential produced by 25 amperes through 100 ohms = 2500 volts. Capacity $E. M. F.$ is one quarter period ahead of the current through the condenser that produces it, consequently the $E. M. F.$ that compensates for capacity $E. M. F.$ is one quarter period behind the current through the condenser. For this reason in Fig. 7, E_r is plotted vertically and E_k at right angles to it on the left. The resultant of these $E. M. F.$'s or the diagonal of the parallelogram that they form is found to have a value of 10,300 volts. The current, therefore, that will be established through this circuit at a pressure of 10,000 volts is $\frac{10{,}000}{10{,}300} \times 25 = 24.3$ amperes.

The next problem is given for the circuits represented by the diagram in Fig. 8. The circuits are made up of sections posessing capacity, self-induction, and non-inductive resistance indicated by L, K, and R. $K = 5$, $L = .5$ and $R = 100$. A current of 25 amperes will be used for the purpose of determining the resultant positions of the various values concerned. In the problem solved in Fig. 7, it was found that 25 amperes through a capacity

of 5 microfards produced a pressure of 10,000 volts. Through a self-induction circuit this current will produce a pressure of $E_s = C\, 2\pi \sim L$.

$$\therefore\ E_s = 25 \times 2\pi \times 80 \times .5 = 6250 \text{ volts.}$$

The fall of potential caused by 25 amperes through 100 ohms = 2500 volts. We have now to determine the resultant of the



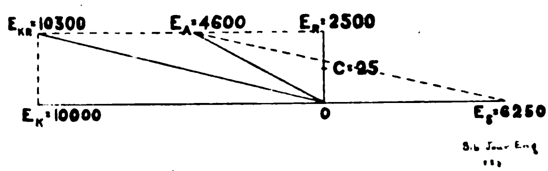


FIG. 8.
FIG. 9.

three *E. M. F.'s* necessary to establish the current of 25 amperes against the fall of potential through *R*, the capacity *E. M. F.* produced in *K*, and self-induction *E. M. F.* developed in *L*. These values are plotted in proper amounts and positions in Fig. 9, and the resultant is determined in the same manner as one determines the resultant of a number of motions of a single body in mechanics. We first combine E_r and E_k and get as a resultant $E_{kr} = 10{,}300$. E_{kr} and E_s are now combined, and we obtain as a resultant $E_a = 4{,}600$ volts or the pressure that the alternator must furnish to set up 25 amperes through the circuit. The current, therefore, that would be established through this circuit at a pressure of $10{,}000 = 25 \times \dfrac{10{,}000}{4{,}600} = 54.2$ amperes. The reader should note particularly in this connection the significance of the fact that the *E. M. F.'s* of self-induction and capacity are opposite in direction when produced by the same current; that because of this natural relation it is possible to so arrange the capacity and self-induction that the *E. M. F.'s* produced by current through them will exactly balance each other. The impressed *E. M. F.*, therefore, needed to set up current through such a circuit is merely that which is necessary to overcome the resistance according to Ohm's law.

Two problems are next given for the circuit in Fig. 10. Here we have one circuit through a condenser in parallel with one through a circuit of non-inductive resistance. For the first of these $R = 100$, $r = 0$, $E_r = 10{,}000$, $K = 5$. What resultant current will the alternator furnish to these two circuits? It is evident that the current through R will be 100 amperes, while in the above problems we have already determined that an *E.M.F.* of 10,000 volts will establish 25 amperes through a condenser having a capacity of 5 microfarads. One hundred amperes as the current through R, will be established in unison with the impressed *E.M.F.*, while the capacity current of 25 amperes will be one-quarter period ahead of the impressed *E.M.F.* The diagonal formed by these two valves (see Fig. 11) gives as the resultant, 103 amperes, or the current that the alternator will furnish

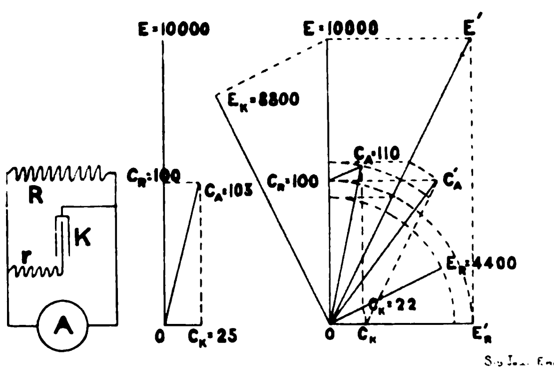


FIG. 10. FIG. 11. FIG. 12.

through the combined circuit. The second problem for Fig. 10 is like the first except that r has a value of 200 ohms. The solution is given in Fig. 12. This figure looks a little complicated at first sight. It is really, however, just as simple as the others. Some additional construction lines have been used to show that after the relative positions of all the *E.M.F.*'s and currents have been determined that the final results may be reduced to any desired impressed *E.M.F.* of the alternator graphically as well as by the arithmetic method of proportion that we have used in the problems that have preceded. As in the first of these two problems the current that the alternator will furnish through two circuits in parallel is desired in addition to the relative positions of the currents and *E.M.F's.* For determining these relative positions we will assume that a current of 25 amperes is estab-

lished through the circuit *rK*. The fall of potential through $r = 200 \times 25 = 5000$ volts.

The capacity *E.M.F.* produced in K is $E_k = \dfrac{C}{2\pi K \times 10^{-6}} =$ $\dfrac{25 \times 10^6}{2\pi \times 5 \times 80} = 10{,}000$ volts.

In fig. 12, $E = 10{,}000$ volts, is plotted as the *E.M.F.* that overcomes the capacity *E.M.F.* of 10,000 volts developed by the current of 25 amperes. This *E.M.F.* is one quarter period behind the current, and, therefore, one-quarter period behind the fall of potential that the current produces through r, for this reason the fall of potential of 5,000 volts is plotted in the diagram on the horizontal to the right as E_r'. The resultant E' of these *E.M.F's* is the *E.M.F.* necessary to set up 25 amperes through the circuit *rK*. It is usual to have the impressed *E.M.F.* assigned to the vertical position, as the positions of all other values are generally referred to that of the impressed *E.M.F.* We will, therefore, rotate all values in the diagram through an angle equal to $E'OE$. At the same time that this rotation takes place all quantities are diminished in the ratio of E' to E. This is done by using as the new rotated values the projections of the old values on the lines occupied by the new values. This operation diminishes all values in the same proportion, giving us the results that would be obtained with an alternator pressure of 10,000 volts. E' or the pressure that the alternator must furnish thus becomes $E = 10{,}000$ volts in the vertical position, the capacity *E.M.F.* takes the position $E_k = 8{,}800$ volts, and E_r' takes the position of E_r equals 4,400. The value of E_r as the projection of E_r' is obtained by projecting the length of E'_r measured along E', on to the line of E and the value 4,400 volts, thus obtained, is the length of the line E_r. C_a' is the resultant current with an alternator pressure of E'. C_a' is rotated so as to coincide with OE', and from there is projected through the angle $E'OE$. The projection obtained is the resultant C_a for 10,000 volts, and is equal to 110 amperes. The component of the current C_r by the same amount of projection is found to be 100 amperes and C_k, 32 amperes.

The final problems for this series are given for the circuits of Fig. 13. Here we have an alternator furnishing current through a circuit possessing self-induction in series with two circuits in parallel, one made up of non-inductive resistance and the other of a condenser. In each case it is desired to know what pressure the alternator must furnish in order that a pressure of 10,000

volts be maintained between the terminals of R. For the problem as solved in Fig. 14, $L = .1$, $R = 100$, $K = 10$, $E_r = 10{,}000$. Since R has a resistance of 100 ohms, a pressure of 10,000 volts will establish a current through it of 100 amperes. The resultant value of the currents set up through R and K is the current that is established through L. When R is subjected to a pressure of 10,000 volts so is K. The current that will be established through K at a pressure of 10,000 volts $= C_k = E\,K\,2\,\pi \sim 10^{-6}$.

$C_k = 10{,}000 \times 10 \times 2\,\pi \times 80 \times 10^{-6} = 50$ amperes.

This current of 50 amperes is one-quarter of a period ahead of the impressed *E.M.F.* that establishes it, and is given a corresponding position C_k in the diagram. The diagonal of the parallelogram C_a, formed by C_k and C_r has a value of 112 amperes and is the current that the alternator must furnish through L to the non-inductive circuit R in parallel with the capacity circuit K. A current of 112 amperes through L will produce a self-induction *E.M.F.* equal to $C_a L\, 2\,\pi \sim = 112 \times .1 \times 2\,\pi \times 80$ $= 5600$ volts. The component part of the alternator *E.M.F.* that compensates for the self-induction *E.M.F.* of 5600 volts will have to be one-quarter period or 90 degrees in advance of the current that produces the self-induction *E.M.F.* Accordingly E_s ($= 5600$)

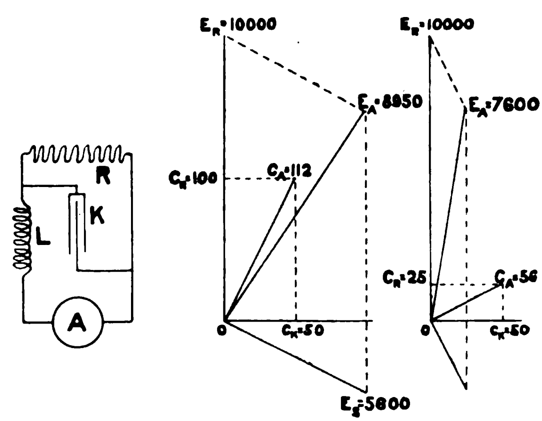


FIG. 13. FIG. 14. FIG. 15.

is plotted in the diagram at right angles to C_a. We have then as the resultant of the component pressures to be furnished by the alternator, the diagonal value $E_a = 8950$ volts.

The second problem for this circuit differs from the first in that $R = 400$ instead of 100 ohms. The value of the alternator pres-

sure that will maintain a difference of potential of 10,000 volts between the terminals of R is again desired. The solution for this problem is given in Fig. 15 and is accomplished in precisely the same manner as that described in connection with Fig. 14. The pressure required from the alternator in this case is found to be $E_a = 7600$.

In these last two problems we have developed the interesting fact that the capacity of underground cables may sometimes cause the pressure on the cable to be higher than that which is developed by the alternator itself.

STORAGE CAPACITY IN LAKES AND RESERVOIRS.*

BY ELON HUNTINGTON HOOKER, A.B.

The problems of water supply are among the most interesting to the young engineer, as they involve a field of research to which he has ordinarily given little time, and the study of statistics and data whose practical value he learns for the first time.

To the country selectman who knows there is a lake somewhere in the distance from which his town wishes to draw its water supply, the main problem appears to be "How shall the pipe be laid?" Yet there is a deeper and more fundamental question which is first suggested to the engineer, the investigation of which must antedate all determination of the practical questions of pipe-laying. The question takes this form: "What is the value of the available supply from the watershed and how much storage will be required in the lake or reservoir?"

It is then, with this last question that we are now concerned, and in order to start on grounds of mutual understanding let us first define our terms.

In general, reservoirs have two duties to perform. First, to make possible during seasons of floods and droughts alike, the delivery of a regular supply at or near the place of distribution. A reservoir doing such service would be called a *Storage Reservoir*. And secondly, the duty of providing for the daily and hourly fluctuations of demand by the city. Reservoirs for this purpose are called *Distributing Reservoirs*.

Storage, then, may be defined as the accumulation of water in a reservoir in times of plenty to tide over the periods of drought.

* A paper read before the Cornell University Association of Civil Engineers, January 12. 1894.

The object of storage is to insure a uniform conduit draught for any town depending on the watershed for its source of supply.

For determinations of storage, this method was formerly most commonly adopted. Assume a definite value for the storage volume, consider the reservoir full at the beginning of the year, to this volume add the inflow and subtract the offlow for each month in turn of an average year, and thus determine the storage at the end of every month. If, in any case, the result shows a deficiency, the assumed storage was too small and a recomputation must be made with a new initial storage.

This method was an advance over mere guess work, or the direct application of experience gained on one watershed to the solution of storage problems on another, with no account taken of determining conditions totally different; yet it was a cumbersome and indirect solution, and the results are misleading.

Since the purpose of the storage reservoir is to provide for the fluctuations of supply and demand during an indefinitely long period, it is not sufficient to take an average year for the determining condition, as the required storage is a function not only of the absolute values of supply and demand, but also of the relative arrangement of these values.

Hawksley has taken a step in the right direction in his empirical formula based on the conditions obtaining during a period of three consecutive dry years.

His formula is as follows:

$$Z = \frac{1000}{\sqrt{R}}$$

where Z is the number of days storage required and R is the average rainfall in inches during the three consecutive dry years, the average rainfall for a dry year being assumed at $\frac{5}{6}$ of the average rainfall for an ordinary year.

Also the volume stored in one day is

$$T = B + C + V - D,$$

where

$B =$ Demand of the town,
$C =$ Compensation to the stream,
$V =$ Evaporation from reservoir,
$D =$ Dry weather flow into the reservoir.

Here all quantities are estimated for 24 hours.

$Z =$ 100 to 250 days for England and English conditions. These formulæ would only be applicable where, as in England, the compensation to the stream is fixed by law at ⅓ of the available supply.

The main criticism to be made on Hawksley's method is that it covers only a single period of three dry years. It is not safe to rely on a single period of drought, for it may happen that a long series of alternate periods of plenty and of drought may follow each other. Perhaps no single drought may have excessive overweight and yet the sum total of these deficiencies may be very great.

As an actual fact, applying Hawksley's rule to the storage provided at Liverpool, Manchester, Dublin, and Edinburgh, we find that his results fall short of the actual by from 20 to 30 per cent.

The first really satisfactory method of determining the storage required is shown in the following graphic solution proposed by W. Rippl and described by him in a paper read before the Austrian Society of Civil Engineers. As all subsequent solutions have been more or less directly based on this paper, we will look into his method somewhat in detail.

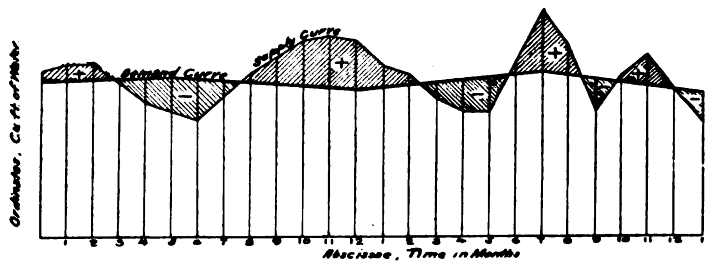


FIG 1

On an axis of abscissae, as shown in Fig. 1, the months are layed off for each year of the period under consideration, and the demand of the town in cubic feet for each month in turn plotted as ordinates, a slightly undulating curve drawn through the points so plotted gives the demand curve as shown above. In the same way the supply curve is plotted, and represents available rainfall from the watershed.

Whenever the supply curve rises above the demand curve we have a surplus on hand as indicated by the shaded areas marked plus in the figure, and when the demand curve rises above a deficiency is shown for the period indicated.

From Fig. 1 the surplus or deficiency for each month can be scaled off and used in turn in the construction of the mass curve shown in Fig. 2.

Here again abscissae represent months and years of the period involved, but the ordinate at each month represents the algebraic

sum of all surpluses and deficiencies from the beginning of the period up to the time then ending. A study of this mass curve will reveal the following properties:

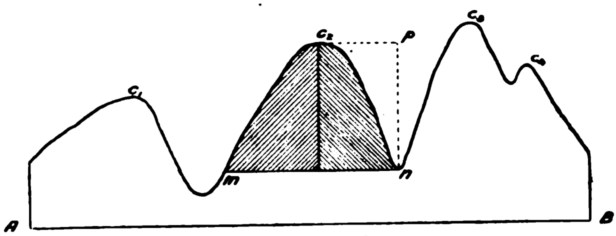


FIG. 2.

The surplus or deficiency, during the interval between any two points on the axis of abscissae, is represented by the difference of the corresponding ordinates. An ascending part of the curve then shows an increasing reservoir supply, and a descending part a decreasing supply, while crests and hollows show instants when demand and supply are balanced.

Take any crest as c_2, Fig. 2. Draw the horizontal lines *mn*. and c_2p. The ordinate pn represents the total deficiency during the period c_2p and therefore the storage required to cover the deficiency during that period.

The line mn, by its intersection with an ascending part of the curve at m, shows the point of time at which the storage must begin in order to cover the deficiency pn. During that period then, demand and supply are equal and all deficiencies are made up by corresponding surpluses. Mn may be called a ***balancing line.***

Fig. 3 shows a mass diagram more in detail.

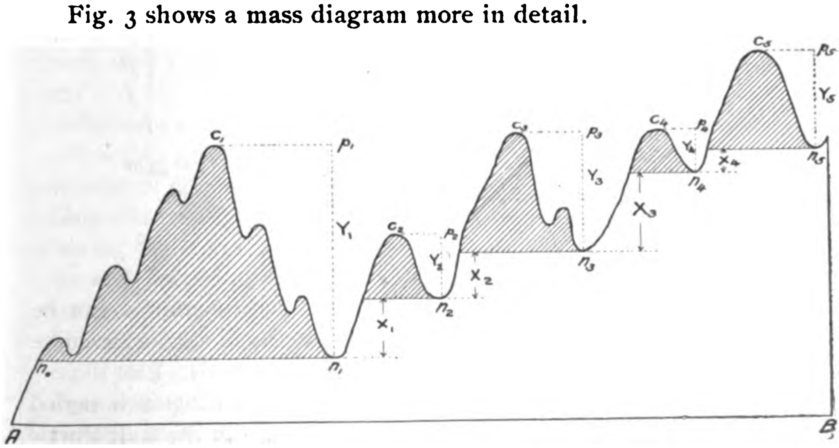


FIG. 3.

Through the hollows n_1, n_2, n_3, etc., balancing lines may be drawn, marking off the periods during which the surplus stored during one part must be used to conteract the deficiency during the other part of the same period.

The storage represented by X_1, X_2, X_3, X_4, etc., is in excess and may be allowed to flow off.

The ordinates Y_1, Y_2, Y_3, etc., measuring the difference between the maxima and minima of one period represent the storage volume required for that period.

The value of the ordinate Y which is greatest for any one period represents the amount of storage required of the reservoir for the interval of time under consideration.

The period in which this greatest value of Y occurs is the critical period. In Fig. 3 the period n_0–n_1 is the critical period, and during it, the storage must be sufficient to cover all deficiencies.

The mass curve may become a straight line parallel to the axis of abscissae for such intervals as the demand exactly meets the supply. Such periods would rarely occur, however.

Another graphic solution of the problem, presented before the Liverpool Engineering Society (*vide* Proc. vol. 13, p. 53), is, in substance, as follows:

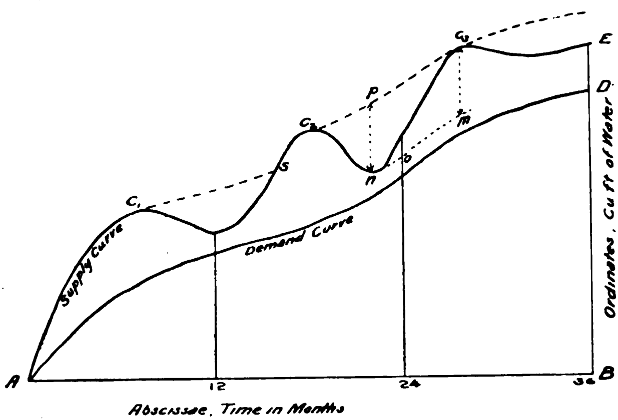


FIG. 4.

Determine the monthly increments of both supply and demand in cubic feet of water. Add these two quantities and form two series giving the total supply and the total demand up to the end of each month from the commencement of the period. Plot these series as ordinates, using months as abscissae, so that each ordinate will represent the total demand or supply up to the time then

ending. The curves through these points will have the following properties, *vide* Fig. 4.

(a) The inclination of the curve to the axis of X marks the rate of increase or decrease of the quantity represented.

(b) When the supply curve is inclined most storage may take place; when the demand curve is inclined most storage is being drawn down.

(c) Draw lines as c_1s, c_2c_3, nm, etc., Fig. 4, parallel to the demand curve and touching the supply curve at the points of inflexion c_1, c_2, n, c_3, etc.

The total amount of loss or gain at any point is the difference between the ordinates of the supply curve and those of the dotted line parallel to the demand curve.

(d) The maximum value of this ordinate is the storage capacity required.

In Mr. Fitzgerald's study of the Sudbury River and Lake Cochituate water sheds, he has followed the general method proposed by Rippl, and has tabulated some interesting information.

The data used cover the period from 1875–1890 and include two years of unparalleled drought, following each other closely. Thus we have not only a long period covered, but one including the extremes of condition.

One table gives the storage required in millions of gallons for different daily draughts of from 100,000 to 900,000 gallons per day, per square mile of watershed, for varying percentages of water surface on the watershed.

Its main value, as suggested in Mr. Fitzgerald's paper, is that it enables one to determine the probable storage required in different reservoirs when they are scattered over the watershed, and each has a different relative amount of water surface tributary to it.

Another table gives the period during which the water surface will stand below high-water mark for different draughts of from 100,000 to 900,000 gallons per day, per square mile of watershed. This table is of value as showing the probable growth of vegetation on the exposed bottom, which, when flooded, will add to the impurity of the water. In the same paper, the author proposes the following method of computing storage, which will be seen at once to differ but little from Rippl's method:

He plots the flow of the river and assumes a draught line. The algebraic sum of the ordinates from the flow line to the draught line will give the required storage for the period.

The proper draught line to consume the full capacity may be obtained after one trial by a simple proportion and the storage computed again as before.

Mr. Frederic P. Stearns, in his report to the Massachusetts State Board of Health, has presented a table in which a valuable refinement is introduced. Mr. Fitzgerald has assumed that the evaporation from water surfaces just equals the rainfall on them. Mr. Stearns has tabulated the storage required to make available different volumes of water per square mile, of land surface only, per day from watersheds with different percentages of water surface where a correction is made for the effects of evaporation and rainfall on the varying percentages of water surface.

A still further refinement might well be introduced which would take into account the varying area of water surface as the reservoir surface rises and falls.

EVAPORATION.

We sometimes find ourselves neglecting this factor as of little weight in the ordinary problems in hydraulics, but its influence on storage can not be ignored.

The available supply from a given watershed must be the total rainfall on the surface less the amount lost by evaporation and other losses, such as percolation, absorption by vegetation, etc. These latter losses, in a well constructed reservoir, are of little importance as compared with the evaporation which is so great that in some discussions of this problem it is considered as wholly taking up the rainfall on the reservoir surface proper. The evaporation from a water surface is much greater than that from the ground and its value for the climate of Boston is seen from the following Table taken from Mr. Fitzgerald's experiments on the Chestnut Hill Reservoir.

These depths are in inches and represent the means of the values for each month, covering the period from 1875 to 1890. The values are usually obtained by plotting the observations for each year and through them drawing the nearest regular curve possible. The values for each month are then scaled from this curve.

January, . . .	0.96	July, ...	5.98
February, . .	1.05	August, . . .	5.50
March, ...	1.70	September, . .	4.12
April, ...	2.97	October, . . .	3.16
May, ...	4.46	November, . .	2.25
June, ...	5.54	December, . .	1.51
		Total, ...	39.20 inches.

Fig. 5 shows a mean monthly evaporation curve and is a graphic representation of the above table.

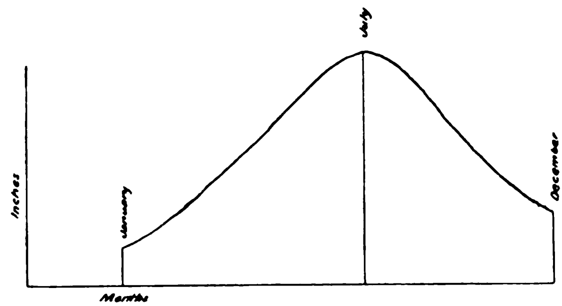


FIG 5

RAINFALL AND OFFLOW.

To attempt to discuss evaporation, available rainfall and storage in the limits of this paper would be at once recognized as impossible, and hence we shall only glance at evaporation and rainfall long enough to see what units are to be used to subserve the purposes of our investigation and where we are to look for information on these subjects.

The United States Weather Bureau keeps records of rainfall which are usually accessible to the engineer, though more or less unreliable for his purposes. In many cases observations are made from the tops of tall buildings where the temperature is different from that of the surface elevations with which the engineer deals. Again, the angle at which the rain falls may materially affect the size of the rain-gauge aperture perpendicular to the direction of the rain drops.

The most reliable results are usually obtained where the rainfall records are kept, under the supervision of the engineer, directly on the watershed itself.

These records should give the depth in inches of rainfall for each month of the year, carefully including snow as well which may be reduced to water.

These depths in feet multiplied into the area of the watershed will give the total rainfall in cubic feet for each month of the year or years covering the period of observation.

Observations of this character have been collated by Mr. Fitzgerald for the Boston Water Works, by Mr. Alphonse Fteley for the Croton Watershed, and may be obtained from the Philadelphia Water Works reports for the watersheds of the Tohicon,

Neshaminy, and Perkiomen rivers, which furnish Philadelphia's supply.

As to the proportion of this rainfall which can be collected in the reservoir for storage purposes we can say only a word, It is a problem on which a treatise might be written. In general the method of determining these percentages available is made by gauging the flow of the stream for certain known depths of rainfall and deducing a percentage of collection for each month of the period considered.

Percentages of offlow will of course be largely affected by the character and configuration of the watershed. A steep, rocky drainage area would be called a "quick" watershed and would yield large percentages while more sloping and better cultivated land would yield small proportions of offlow. Not only is the offlow determined by the character of the surface but is also a function of the season of the year and the temperature. In winter when the ground is frozen, a larger percentage will flow off than in summer and in some cases, notably in the month of March, we may even have the apparent paradox of a collection of 200 per cent. for a given rainfall. This is easily understood when we remember that we are likely to have in the spring a storage of rainfall on hand, in the form of snow, which is the accumulation of previous months, but which melts and runs off during March, thus raising its percentage of offlow.

As is seen at once no general percentages can be laid down and the engineer cannot be too strongly cautioned, in all these determinations, against using results obtained from a certain set of conditions and applying them to another case where the conditions may be wholly dissimilar.

Having thus, in a general way, arranged the data, determined the depths, of rainfall, inches of depth collected for each month, area of watershed, area of water surface, depths of evaporation for each month and amount of compensation water required, having assumed, as well, a regular conduit draught, we may apply Rippl's graphic method directly and determine the amount of storage required. The storage problem usually presents itself to the hydraulic engineer in this form. Given a certain possible amount of storage in the lake or resevoir, how much water can we expect to make available for water supply purposes without causing excessive fluctuations in the water surface?

We may make a computation for a series of values of conduit

draught and plot the resulting fluctuations in the reservoir surface. That conduit draft will then be chosen whose resulting curve does not fluctuate beyond the limits fixed by the natural conditions inherent in the reservoir. These natural conditions will vary with the situation of the reservoir and must be studied independently in each case.

If the reservoir is a lake surrounded by cottages, then the fluctuations of the lake are likely to be limited by the elevation of boat-houses, lawns, and houses above the former water surface, while the lengths of periods during which the lake may be drawn down will be limited by the rapidity with which the uncovered shores become overgrown with marshy vegetation.

Such growths are among the most active of the contaminating agents and afford a strong argument against excessive fluctuations in the water surface.

And now in conclusion, let us remember not to accept blindly any generalizations on such a subject as Water Storage or Precentages of Offlow from watersheds. These are matters to be studied in the light of their own peculiar conditions for each separate case and we can use what has been printed on the supject more safely as showing us methods of work than as giving us results which can be generally adopted.

MECHANICAL REFRIGERATION—ARTICLE I.

BY R. C. CARPENTER.

Systems of mechanical refrigeration are now successfully constructed and are extensively employed, either for maintaining a low temperature or for the manufacture of ice.

Some practical acquaintance with the processes successfully employed, seems of importance to the mechanical engineer, for this reason the Director of Sibley College has considered it wise to include in the equipment of the department of Experimental Engineering, machinery which illustrates the best practice in the construction of this class of machinery, and such machinery is now in process of installation. The present series of articles is intended to gather together information regarding the method of operation of these machines, and put it in a form available for students' use.

The literature devoted to this subject is not extensive. The best available work is, no doubt, "Ice Making Machines," by M.

Ledoux, revised by Denton and Jacobus, Van Nostrand Science series, cost 50 cents, which all students are advised to obtain. In addition, are various papers, Transactions Mechanical Engineers, of which I may mention, Thermodynamics, by Geo. Richmond, and various Tests by Professor D. S. Jacobus. Also, Thesis of Beals and Shantz, 1893, Sibley College. See also Thermodynamics, by Professor De Volson Wood and Professor Peabody.

The present article is intended to give, *first*, a general idea of the underlying principles involved, and *second*, the general system of construction in each class of machines.

GENERAL PRINCIPLES.

The refrigerating machine is a species of heat engine, in which, by means of mechanical work, heat is transferred from one substance to another, the effect being to reduce or lower one temperature and increase the other. The ideal case for this, as for the steam engine, the hot air engine, and other heat engines, is the reversible engine describing a Carnot cycle.

For the heat engine which converts heat into work, the engine is run forward or direct; for the case under consideration, the engine must be reversed, or run backward. The following illustrations will render this statement clear.

Carnot's engine, when working direct, takes from the source of heat A, a quantity H_1, changes a part AW into mechanical energy, and rejects the remainder H_1 to the refrigerator b. We have for the efficiency,

$$E = \frac{AW}{H} = \frac{H - H_1}{H} = \frac{T - T_1}{T} \quad \text{(a)}$$

If the engine be run backward so as to describe its cycle in the reverse order it takes heat from the refrigerator, adds to it the heat equivalent of the work of the cycle, and delivers the same to the source of heat and thus becomes a refrigerating machine.

As an illustration, suppose that any substance is compressed adiabatically, in which case its temperature will rise, next that it be compressed isothermally, in which case the temperature will remain constant provided the heat generated be absorbed and removed, then allowed to expand adiabatically and isothermally, until the working substance is in its original condition. During the last operation heat must be supplied the working substance, to maintain a constant temperature, so that this case represents the flow of heat by means of mechanical work from a colder to a hotter body.

The expression for efficiency is the same as in equation (a) but since mechanical work must be done on the substance, the highest efficiency is obtained when there is the greatest possible transfer of heat, with least mechanical effort.

THE AIR REFRIGERATING MACHINE.

As an illustration suppose that the working substance be air, and that it be compressed by mechanical means to an absolute pressure of 100 pounds per sq. inch, the heat which is generated being removed by a water jacket, so that the temperature at the end of compression is the same as at the beginning. The compressed air, by virtue of its pressure, has considerable potential energy and if permitted to expand against a resistance will do considerable mechanical work, which will be accompanied by a fall of temperature. It was experimentally demonstrated by Joule * that the temperature of air will remain constant if it expands without doing external work, which leads to the conclusion that the externai work, due to the separation of the particles is proportional to the change of temperature, so that no heat can be liberated or absorbed by the mere act of expansion. From this it is inferred that the external work done by the expanding air is a function of the heat removed. The work and consequent removal of heat tends to lower the temperature of the working air. Thus if M be the weight of working air, other symbols as in equation (a), we will have $AW = H - H_1 = .238\,M(T - T_1)$. From which $T - T_1 = AW \div 0.238\,M$ (b). The work of the expanding air can be utilized in operating the piston of the compressor, in which case the only external work required is that of overcoming the friction and thermal losses of the machine.

These losses are in general considerable, so that although refrigeration by compressed air has been and is extensively practiced, it is less economical than processes employing ammonia, or similar liquids.

It is interesting to note the form of the more successful of this type of machines, some of which have been in operation since 1849. The Windhausen machine which was operated during the Vienna Exposition, had a capacity of 30 cwt. of ice per hour. In its construction it consisted of a single cylinder, each end of which was alternately a compressed air engine and a pump for compressing the air. The compressed air was delivered to a

* Article Hydromechanics, Encyclopedia Brittanica.

cooling vessel and from thence to one end of the cylinder, being admitted by a valve motion, and acting in its expansion to move the piston and help to compress the air drawn in at the other end. The exhaust air after being deprived of its heat by the work of compression, was passed to the cooling vessels and utilized in lowering the temperature of a quantity of brine, or directly discharged for refrigeration purposes. The power required over and above that provided by the compressed air was supplied by an engine.

The Bell–Coleman machine, which is extensively used on ship board for refrigeration purposes, is constructed in much the same manner as the Windhausen, but the operations of compressing and expanding are performed in separate cylinders. The machine consists of three tandem cylinders, and three pistons fixed to a common piston-rod. One cylinder is the air compressor, the other the air engine, while a third is a steam engine which supplies the excess of power needed to move the pistons.

The cycle of operation of the compressed air refrigerating machine consists of the following operations which have already been briefly referred to:

First, compression adiabatically and isothermally.

Second, removal of the surplus heat generated during compression.

Third, expansion adiabatically and isothermally doing work.

Fourth, addition of heat to the working substance, by means of which refrigeration is accomplished; that is, the exhaust air is discharged at a very low temperature and is warmed at the expense of heat stored in the surrounding medium.

With this short description of the method of construction, we can now intelligently consider the general underlying equations for all systems of refrigeration.

GENERAL EQUATIONS FOR THE REFRIGERATING MACHINE.

The cycle of heat exchanges for the refrigerating machine of any class can be written for one unit of weight as follows:

Let $H =$ the original heat of the working substance. $H_1 =$ the heat at end of compression, were none removed by cooling or loss. H_2, the heat at end of compression after cooling. H_3, the heat at end of expansion, supposing none removed for cooling purposes. $K =$ the heat taken up by cooling liquid during or at end of compression. K_1 the heat taken up by the substance during

refrigeration. $A\ W_c$ the mechanical work of compression, $A\ W_e$ the mechanical work done during expansion. We have then the following equations, supposing no thermal losses to exist.

During Compression, $H + A\ W_c = H_1$. (1)
Cooling or Condensation, $H_1 - K = H_2$. (2)
During Expansion, $H_2 - A\ W_e = H_3$. (3)
Refrigeration, $H_3 + K_1 = H$. (4)

In the above equations K_1 is the measure of the refrigerating value, A is equal to 778, by substituting in the above equations we find that

$$K_1 = H - H_3 = H - H_2 + A\ W_e = H - H_1 + K + A\ W_e$$
$$= H - H - A\ W_c + K + A\ W_e = K - A\ (W_c - W_e) \quad (5)$$

That is, the refrigeration possible in the perfect machine is equal to the heat carried off by the cooling or condensing water diminished by the difference of the heat equivalent of the work done in compression and in expansion.

By transposing in equation (5), $A\ (W_c - W_e) = K - K_1$ (6)

As the heat carried off in the condensing water can seldom or never be utilized, the efficiency of the system is the ratio of the refrigeration K_1 to the work, $A\ (W_c - W_e)$; that is, the efficiency E becomes

$$E = \frac{K_1}{A\ (W_c - W_e)} = \frac{K_1}{K - K_1} \quad (7)$$

From consideration of equation (6).

That is, the mechanical work in the perfect refrigerating machine is equal to the heat transferred from refrigerator to source of heat; this was a fundamental proposition and hence can be considered as a check on the accuracy of the work.

In the actual machine, the heat equivalent of the mechanical work is always greater and often considerably in excess, of the transfer of heat, the losses being due to radiation cylinder condensation and friction.

The importance of the various quantities in the above equations will depend upon the nature of the working fluid and the character of the machine. The temperature or limits between which the operation is conducted, will depend upon the conditions of the problem and the nature of the working fluid. If the refrigerating value of one pound is K_1, expressed in heat units, the maximum difference of temperature can be found by dividing by the specific heat of the working substance.

AMMONIA REFRIGERATING MACHINE.

The working fluids are usually selected among the fixed gasses, or from liquids whose boiling point is very low. The principal freezing machines use either air or ammonia, or a volatile petroleum oil. The general form and method of operation of the air machines has been described, the ammonia machine is of two general classes, *compression* and *absorption*, in one the compression is performed by mechanical means, in the other by heat and chemical combination. In the *compression machine*, the gaseous ammonia is compressed, by mechanical means, that is by a pump. This compressed gas passes through a coil in a tank filled with cold water, called the *condenser*, in which the excess of heat, K, is removed and the gas liquified. It then passes to the *expansion vessel*, which in general consists of a large coil of pipe immersed in a tank of brine or some liquid which freezes at a very low temperature.

The expansion of the liquid draws heat, K_1 from the brine, thus lowering its temperature. The brine at a low temperature is circulated by mechanical means for refrigeration or ice making. The expanded ammonia is drawn back into the pump and returned to the system by mechanical means.

In some of the compression machines, the clearance spaces of the pump are filled with oil, to prevent the leakage and losses due to clearance spaces; more or less of this oil is discharged with the compressed ammonia, and has to be removed before passing to the condenser. For this purpose a separating vessel, which throws the oil to the bottom, is placed between the compression pump and the condenser. The oil is taken from the bottom of the separator and returned to the pump by a special oil pump. The ammonia liquid, after leaving the condenser and on its way to the expansion vessel, passes through an expansion or throttling valve, which is set automatically or by hand to regulate the supply to the expansion tank. The freezing machine in Sibley College has the oil separator and the automatic valve for supplying the expansion tank.

In the *absorption system* a mixture of water and ammonia is employed. The ammonia gas is driven off from the water and compressed by means of heat, this being easily done, because of its low boiling point. For the operation corresponding to that of mechanical *compression*, are usually employed these vessels, a still, called a *generator*, a drying chamber, called an *analyzer*, an

auxillary heater, called an *exchanger.* The *condenser, expansion tank* and *brine tank* are similar to those used in the compression system.

At the end of the expansion the ammonia gas is absorbed in water, for which it has a strong affinity; it is thence pumped to the heater, and returned to the working system, the water, strongly impregnated with ammonia, being usually kept separate from that of the weaker liquid.

In the latter system, for the heat equivalent of the mechanical work of compression, must be substituted the actual heat required. This heat is usually supplied by steam confined in pipes, and passing through the *analyzer.* Details of construction will be given in later articles.

The fundamental equation of operation can be considered as equation (6).

$$A\,(W_c - W_e) = K - K_1.$$

In this equation K_1 is the heat absorbed by the refrigerating fluid; K is the heat given off during compression. As the work of compression W_c must always be greater than that available W_e, during the expansion, hence we find that K must always be greater than K_1.

RELATIVE VOLUMES.

For the air refrigerating machine, W_e is considerable, for the ammonia machine it is usually wasted and hence, becomes o so far as the practical operation of the machine is considered. The heat capacity of any gas which does not change its state is small, and is equal to the product of specific heat, into weight, into change of temperature. On the other hand when vapors are employed which are converted into liquids during the process of compression and cooling, and then changed to vapors during expansion, the heat capacity of a given weight is increased by its latent heat, which is always comparatively large. It becomes quite evident from the latter consideration alone, that the air machine must for a given capacity be many times greater in size than the ammonia machine.

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NOTICES.

The SIBLEY JOURNAL board takes this opportunity to inform the students of Sibley College that there are two places on the board for next year that are to be filled by competition, one from the class of '95 and one from the class of '96. Any matter showing the ability of the writer is acceptable. It is not necessary that it be suitable for publication, though such matter is preferred.

Subscriptions to Vol. VIII of the SIBLEY JOURNAL are now due and may be paid either at Andrus & Church's or to some member of the board.

Any persons sending one or more numbers of the SIBLEY JOURNAL for January, 1893, to Andrus & Church will receive twenty-five cents for the same.

EDITORIALS.

WE are indebted to Professor Osborne of the Architectural department for the use of the plate from which our frontispiece is printed.

OWING to press of other matter we have been obliged to omit Crank Shafts from this issue.

WE present to our readers in this issue, among other articles, an abstract of the paper read by Dr. Thurston before the American Society of Mechanical Engineers, upon the famous Sibley College trial of the Milwaukee Pumping engine. Perhaps no engine-trial of recent times has excited such wide-spread interest as has the test of this wonderful record-breaker, and it is with pleasure that the SIBLEY JOURNAL offers this complete supplement to its former publications of the results of the test, as conducted by Prof. Carpenter and his assistants. The discussion of the paper was interesting from many points of view, professionally, and both practical and scientific and even psychological. We may be able later to give an abstract showing how perfectly the accuracy of the work has been fortified and defended, and some specially interesting and novel phases of discussion, with new facts.

We also publish the first of a series of articles on Mechanical refrigeration by Prof. Carpenter. It is a subject upon which few references can be given, and will be an interesting one to Seniors, for it is the present intention of the Experimental Engineering department to make this the subject of an experiment in the course of laboratory practice.

OPENING OF NEW BUILDINGS.

THE dedication of the new building provided by the State of New York for the work of Dairy Husbandry took place on the 27th ultimo, with interesting public exercises, attended by Trustees, Faculty, State Officers, and interested friends, of the University. The new building, designed by Professor Osborne, is one of the most attractive of all the new buildings on the Campus. It is small, but striking in appearance, and is decidedly an ornament of the grounds of the University. It is constructed of grey stone, is simple in its architecture, but very finely preportioned, is neatly designed as to details and is substantial and

convenient. It is expected to form, in time, a part of the proposed great "agricultural building," long ago designed, and only awaiting the appropriation of the needed funds by the State, before its erection is begun. The interior of the building just completed is divided into rooms appropriated to the various branches of dairy-work, as for butter-making, cheese-making, and accessory operations. A small steam-engine and boiler are in operation in the basement, and supply heat and power for the building and its centrifugal cream-separators, and other machinery. Mr. Eldredge, Instructor in the Department of Experimental Engineering, is the consulting engineer in this branch. The whole constitutes a most valuable and useful accession to the facilities, already extraordinary, of the College of Agriculture. The University and the College and all friends of this great enterprise are to be heartily congratulated upon the outcome of this, the first contribution of New York to the work of its already great and famous State University.

Quite as interesting ceremonies have also attended the formal opening of the Museum of Classical Archaeology, one of the most important, though comparatively inexpensive of all the many contributions, small and great, made to the equipment of the University by the Hon. Henry W. Sage. This collection of casts, representing the noblest products of old Greek art, is considered one of the finest and most discriminatingly selected of such collections as yet imported into the United States. The Curator, Professor Alfred Emerson, has exhibited admirable taste in their arrangement as well as judgment in their purchase. The collection fills and, in fact, crowds, the whole of the great hall on the lower floor of the McGraw building, and constitutes one of the most attractive of all the many characteristic outfits of the different university departments. Visitors of whatever rank or class or vocation, find it difficult to leave the hall, once they have made themselves familiar with its prominent attractions. The casts are all well-made copies of the originals by reputable dealers in works of art, and furnish admirable studies alike, for the artist, the student of fine or industrial art, and the archaeologist, for whom they were especially provided. It is a most important adjunct to the Department of Greek, work in which, as related, especially to Greek life and art-work, is greatly facilitated by its presence. Its distinguished donor evidently appreciated the requirements of modern scholarship in this department when the selection of a recipient for his bounty was made in this case. He,

as well as the Departments concerned in the University at large, is to be as heartily congratulated upon the outcome of his enterprise, as is the College of Agriculture for its added facilities in less aesthetic directions.

A third, and to students in the technical courses and of Sibley College, in particular, even more interesting accession to the material equipment of the University and of the College, has been made with the completion of the new Sibley College Museum and draughting rooms, supplying convenient and comparatively ample quarters to the Department of Marine Engineering, Mechanical Drawing, and Machine Design, under Professors Durand, Cleaves, Williams, and Barr. In accordance with the expressed desire of the donor, Mr. Hiram W. Sibley, and with the well-known preferences of the Director of Sibley College, no formal or public exercises of dedication, or of acceptance of this building will be held. They consider its best dedication to be quietly taking possession, and the introduction into it of its share of the largest body of students in the University, or to be anywhere found in this department of technical work. The growth of Sibley College has not been heralded, or accompanied, by public declamation. It has been so quiet that even its own friends have often failed to realize it or to appreciate the magnitude and importance of the work already performed in the upbuilding of this great college. Such as have observed and understood it have exhibited an appreciation of the efforts of the Director of Sibley College and his staff, which must be exceedingly grateful to them; the more so that such appreciation is so seldom given expression, even where strongly felt, by the average American citizen. Of the most practical and effective form of sympathy and appreciation, that which prompts actual assistance and the lending of a hand in helpful aid of the work, and which is expressed in dollars and cents or their equivalent, Sibley College has received a liberal share; and it is for this form of appreciation, expressed by a few staunch friends of the work and of the University, that all who are interested in the institution are most grateful. The two hundred thousand dollars contributed by the Founder; the fifty thousand dollars just received from the younger Sibley; the contributions to the collections, equipment, and working outfits of the various departments, now coming in by the thousands of dollars-worth, every year, speak in the right tone, and we may well excuse our friends from coming to talk when they send such eloquent proxies to take part in the work

itself in the most effective and satisfactory possible way. But we still need more of such friends and many more such proxies, and every friend of the special work of Sibley College should be constantly engaged in finding such new auxiliaries and in doing, himself, whatever his opportunities may permit to forward the work.

A TRIBUTE TO MR. SAGE.

Mr. Henry W. Sage, on the 31st day of January, completed his eightieth year and received from all sides those hearty and earnest congratulations and affectionate attentions which are due to the man who, next to Ezra Cornell, has done most for Cornell University. His gifts to the University amount to over one million of dollars, and his care of its finances has given it that enormous capital from the sales of its lands which, otherwise, would probably have amounted to but a small fraction of the six millions now obtained or obtainable by its sale at recent market prices. Further than this, in his capacity of Chairman of the Board of Trustees, Mr. Sage has, for many years, given constant and unremitting attention to every detail of the business and general management of the University, and has thus done more than any one, in any other capacity, possibly could, to promote the efficiency and fruitfulness of its internal operations. The day was marked by the inauguration of the Museum of Archæology, which is given its equipment by Mr. Sage, and the ceremonies included an interesting address by Professor Merriam of Columbia. In the evening, the whole body of Trustees and Faculty called upon Mr. Sage, and brief but beautiful addresses of congratulation and good wishes were presented in behalf of Trustees, of Faculty, and of the students of the University. A beautiful silver vase was presented by the Trustees as a testimonial of their affection and respect, and a memorial of the occasion. Mr. Sage responded in his usual earnest and impressive manner, giving assurance of undiminished interest in the great work which he had so long and so successfully prosecuted in behalf of the University. Among the addresses, that presented, beautifully engrossed on parchment by Mr. Harvey D. Williams, the authorship of the first draft of which, at least, is attributed to Professor C. M. Tyler, contains perhaps the most beautiful and touching passages. Thus, our Faculty says :

"Amidst the ceaseless activities of a business career, your thoughts ever turned toward the promotion of the welfare of your country. To you the culture of the young seemed the safest and most ennobling charity, the most enduring means of promoting patriotism, civic virtue, and true, intelligent religion. Your sympathy from the first has been manifest for letters, arts, and sciences, as related by a common bond, as divine instruments of human progress and welfare. If Cicero could say that nature without education has oftener raised men to glory and virtue than education without natural abilities, you, on the contrary, have held fast the faith in the necessity and advantages of education for all mankind, to strengthen abilities, however weak, to afford the young persons, of native strength of mind, a guidance in the way of noblest aspirations."

The address concludes: "We affectionately salute you, on this the eightieth anniversary, thankful that such vigor of mind and body is still yours, that your wisdom is still at the service of the University, in its councils of administration, and that we may hope for you still other years of well-earned rest and gratitude. 'The end of doubt is the beginning of repose.' The solid base of your work here cannot be disturbed. That your remaining years may be full of sunshine and peace, that your hopeful presages of Cornell may 'with the process of the suns,' be unceasingly realized, by those who shall come after us, and that you may return late to the skies, is our earnest prayer."

TECHNICAL EDUCATION IN THE UNITED STATES.

THE paper by Dr. Thurston "On Technical Education in the United States," read before the Engineering Congress at Chicago last summer, and reproduced in part in the issue of this JOURNAL for October of this year, has been called for so frequently that the American Society of Mechanical Engineers, whose council took charge of the work of its department at the Congress, has printed several editions for distribution. On the evening of Monday last, each of the members of the New York State Legislature were supplied with a copy from the office of the governor, by the governor's secretary, Col. Williams, as furnishing information relating to the progress made in this department of public work, especially in other states. The paper contains a considerable collection of statistical matter,

and exhibits the advances made in this country and in Europe, to date, in the promotion of the work which the "Land Grant Colleges" were especially chartered to carry on. In this work Cornell has been very prominent, and the facts presented include many that are most creditable to the University; they can hardly fail to aid effectively in securing for the University of the state that consideration which has been so well earned but of which so little has been accorded. The contrast between the attitude taken by other states toward their universities and held until recently by our own state, comes out into high relief in these historical and statistical statements.

A NEW TECHNICAL INDEX.

One of the most thoroughly essential and necessary habits of a successful engineer is that of carefully systematizing his work, in order that he may cover as large a portion as possible of that enormous field open to him for his professional labors. Any plan that renders easier this, at best, difficult task will be heralded with delight by all. Consequently it is with pleasure that we note the appearance of a new publication which will be a great assistance to the readers of the technical press, in ascertaining what to read on any desired subject and where to find it. We refer to electrical literature, a classified, synoptical index of the current literature of our own and of foreign countries. This magazine is the outcome of the technical index which has heretofore been published in *Electrical Engineering*. This index has gradually expanded, until now, it has developed into a monthly magazine, having a widely extended scope, and possessing several very desirable qualifications. The index is classified under heads, and is so arranged that, if desired, a file may be kept of that part of each number which applies to any particular subject, such as Arc-lamps, Street Railways, etc. A system of double page-figuring is adopted, and only one side of the page is printed upon, in order that any such files may be preserved in good shape. The publication is an exceedingly valuable one to the engineering profession, and we wish for it, in full measure, the high success which it is destined to have at the hands of its enterprising and energetic publisher, Fred De Land, No. 565 The Rookery, Chicago.

The schedule of Sibley College tours which are annually made under the personal direction of our professors, has been announced, and will be published later, with corrections, if such should be made, in these pages.

OBITUARY.

Scarcely a month goes by without bringing us the necessity of chronicling the death of some man who was a leader in the ranks of the engineering profession, or who was famous for his achievements in some branch of science. Heinrich Hertz was a man, who, although only thirty-six years old at the time of his death, January 6, was, nevertheless, widely known for the part he has taken in advancing the science of electricity. He was born in Hamburgh. After taking a degree at Berlin he devoted himself to the study of Physics and became closely connected with such men as Helmholtz and Kirchoff. He showed great genius in this line, and indeed attracted such wide attention as a scholar that he was chosen to fill the place left vacant by Clausius at the University of Bonn. The work for which he became the most famous was that in connection with light-waves, in pointing out the connection between electrical impulses and the propagation of light-waves.

PERSONALS.

'88.

J. P. Disney is in the corps of patent examiners of the U. S. Patent Office. He recently passed number one in an examination for promotion.

W. B. Smith Whaley, is now a mill architect and engineer in Columbia, S. C. He has recently supervised the installation of a large mill plant for the Courtenay Manufacturing Co., of Newsy, S. C. The Charleston *Observer* says of his work :—"The engineering displayed is of a high order and entitles its projector to great credit."

'89.

J. L. Dowling is with the Buckeye Pipe Line Co. at Lima, Ohio.

'90.

H. P. Broughton is a member of the firm of Jas. I. Ayer & Co., consulting electrical and mechanical engineers, St. Louis, Mo.

'92.

Jos. Kuhn, is with the Thompson Steel Works, Pittsburgh, Pa.

Allison S. Capwell is designer for the Singer Sewing Machine Company.

The personal T. B. Corey in our last issue should have read F. B. Corey.

A. R. Henry is assistant engineer of the Robb Engineering Co. Limited, Amherst, N. S.

Jas. H. Dyett can be found with Hard Bros. Manufacturing Co., makers of woven wire goods, at Oneida, N. Y.

Geo. W. Bacon employed by the La Roche Electric Works, Philadelphia, may be addressed at Oaklym, Camden Co., N. J.

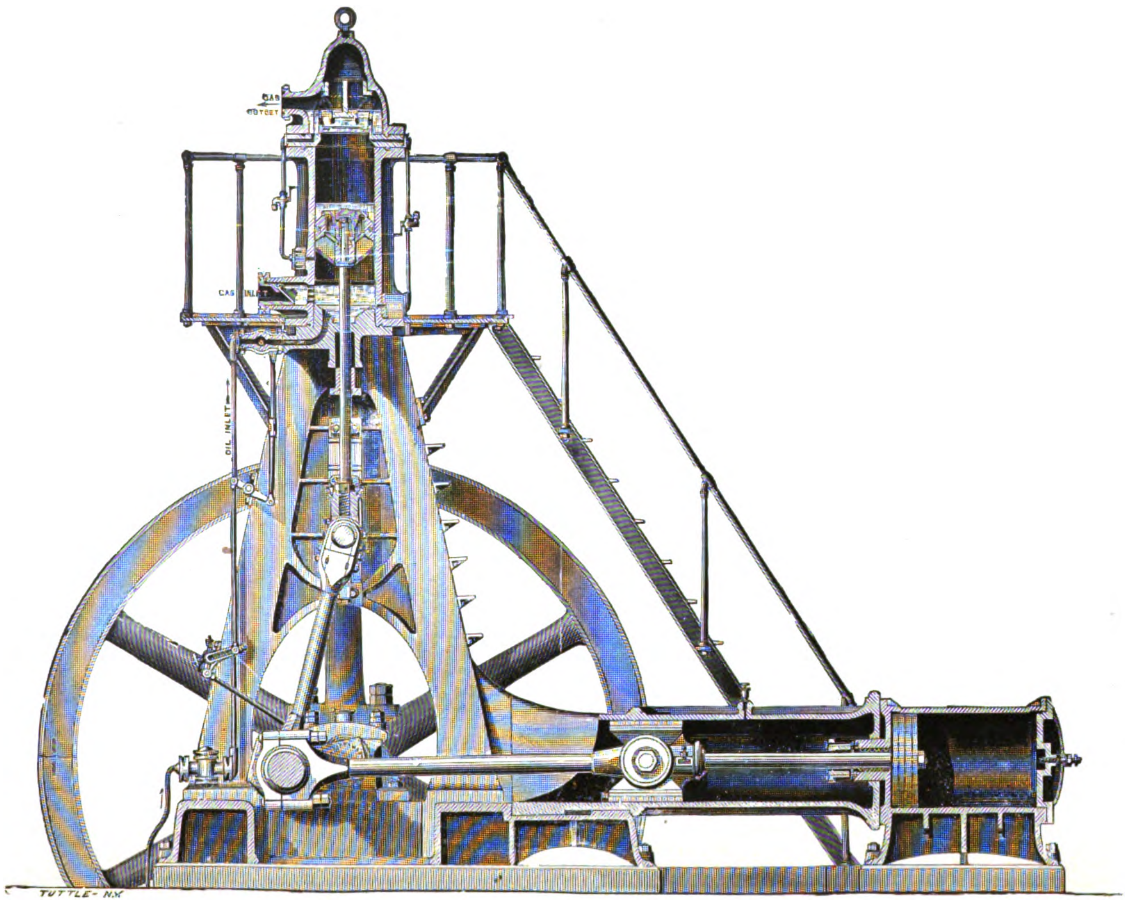
W. G. Starkweather is employed by the E. P. Allis Co., Milwaukee, Wis. He is also instructor of mechanical drawing for evening classes of students.

'93.

S. C. MacNider is pursuing graduate work at the University.

F. R. Frost was elected associate member of the A. I. E. E. at their last meeting.

Chas. Dunn is employed by The Robert W. Hunt & Co., consulting engineers, The Rookery, Chicago, Ill.



SECTION OF REFRIGERATING MACHINE.—Fig. 4.

THE SIBLEY
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IN CORNELL UNIVERSITY

"The leading object shall be, without excluding other scientific and classical studies, and including military tactics, to teach such branches of learning as are related to Agriculture and the Mechanic Arts, in such manner as the legislatures of the States may respectively prescribe, in order to promote the liberal and practical education of Industrial Classes in the several pursuits and professions in life."—[An act donating public lands to the several States and Territories which may provide Colleges for the benefit of Agriculture and the Mechanic Arts, July 6, 1862.]

AN ADDRESS TO YOUNG ENGINEERS.

BY COM. MELVILLE, ENGINEER-IN-CHIEF U. S. NAVY.*

GENTLEMEN :—

I have felt very much flattered by the invitation of the head of your department to make you a short address on engineering matters, because it is a decided compliment to be asked to say something to the bright young intellects which are here being moulded for the profession of which I have the honor to be a member. Naturally I am not expected to deliver anything in the way of a lecture on subjects covered by your curriculum, because your professors are much more competent to treat such subjects than I am. But I presume I have been asked to speak to you so that I might give you the benefit of advice based on my experience as an engineer of over thirty years standing. I shall, therefore, endeavor to say a few words, and trust that some, at least, may be helpful to you ; if not now, at least after you have graduated.

First of all, I want to impress upon you the fact that you are an extremely fortunate set of young men. When I was a lad we had few, if any, schools of engineering, and in every way our opportunities for professional training were far inferior to those

* A lecture delivered before Sibley College, Feb. 26, 1894.

which are now at the convenience of our young men in every part of the country. I am not quite contemporaneous with the great leaders of the profession who laid the basis of our present knowledge, but I am not very far behind them ; and my experience covers a number of the important experimental stages in the advancement of mechanical engineering.

With the advantages possessed by you in the shape of splendid text books and able professors, it is probably hard for you to realize that not so very long ago there was a time when the engineer had not the splendid lot of precedents to which you can now refer, and when many of the problems, which are now practically solved, or at least, nearly so, were so thoroughly unsettled that very able men differed decidedly in regard to their solution. I emphasize this because I believe it will be helpful to you to realize that you are enjoying special facilities.

At the same time I want to caution you that, notwithstanding all your advantages, your course here is, after all, only preparatory to your battle with life. It is impossible for text books to be written so that they can cover all the cases that may arise. Your time is too limited and the books would be too big. All that can be done is to state general principles and the more important features. Your professors, of course, develop these matters in their lectures and point out to you the limitations ; but a great deal of the most valuable information that you will get will have to come from your own experience and reading after you have graduated. I have been told by some of the brightest young men who have been associated with me, and I am sure that your professors will bear me out in this, that there is a tendency on the part of young men when they leave a technical school to think that there is little, if anything, left for them to learn. I want to warn you against this frame of mind, which will be productive of nothing but harm. As a matter of fact, when you graduate you will just have begun to learn ; and if you realize that your training has enabled you to properly appreciate that you have only mastered the rudiments, you will then be in excellent condition to go on and improve. The truth is that your education is, in a certain sense, simply a tool for use in your future work. You have been trained to study, to investigate, to weigh facts and draw conclusions ; and this is of very much more value than the separate concrete facts you have learned.

Probably the thought will come to you sometime shortly after your graduation that older men in the profession, with whom you

are thrown in contact, do not seem to know as much as you do, and yet are in receipt of higher salaries, and their opinions are given very much greater weight. It may be hard for you to appreciate this at the time, but advancing years will lead you to the conclusion, which I now tell you,—that the greatest value of the engineer comes from mature experience and judgment, which, of course, can only come with years. It seems so easy to the young man who has never had experience to solve everything by the rules in his text-books ; but the older men know by sad experience that there are often so many items in the problem that cannot be covered in the text-book, that he simply uses those rules as a help. He has learned, as the result of many failures on his own part and of others, what to avoid and what to seek for, and it is this matured experience which makes him so much more valuable than the younger man.

Nothing could be further from my thoughts than any wish to discourage you by these statements. On the contrary, I want to encourage you to adopt methods which will give you this experience as soon as possible. Never lose an opportunity to gain professional information. When you hear older men discussing problems, weigh carefully what they say, and make a note of any information you may have gained. Be systematic in your reading and in your observation, and never be afraid to confess ignorance. My experience has shown me that the very ablest men are the quickest to ask for information from those who are in a position to give it.

Another point I want to impress upon you is not to undervalue the importance of manual training. I understand perfectly that you are being trained to be engineers and not workmen ; but all experience goes to show that the greater one's skill in manual labor, the better fitted he becomes for his work as a mechanical engineer. The splendid workshops attached to all our great technical schools have the course of instruction so systematized, that, in an incredibly short space of time, the engineering student becomes creditably proficient in manual work. In the old apprenticeship system there was a tremendous waste of time in keeping the boy at certain kinds of work long after he had acquired as much skill as was necessary. In your course, time is so precious that it has been distributed to the best advantage. The advantage of this manual skill is the knowledge it gives the engineer of the possibilities of the workshops ; and, in this connection, I want to emphasize the importance of rendering yourself

familiar, at as early a stage of your professional career as possible, with the possibilities of all the different tools which handle the work designed by the engineer. Such knowledge frequently makes all the difference between a successful and an unsuccessful design. The engineer who is thoroughly familiar with the details of shop work can make his design so that it will be easy to cast and easy to finish; while another designer, without this knowledge, may make a design which will fail in the foundry, or be enormously expensive in its finishing. In my experience I have sometimes been dreadfully disgusted by what I have called the damnably ingenious draughtsman, who gets up plans that appear beautiful on paper, but to the practiced eye are entirely unsatisfactory for the reason that they would be so difficult to produce.

I would say a word also about the literary side of your training. I fear that there is sometimes too little attention given to this. The young engineer is apt to regard the literary feature as something outside of his work, and belonging rather to the training for the bar and the pulpit. In my judgment this is a great mistake. The engineer, of course, does not care to go into the elaborate literary training required for a man who is going to make literature a profession; but he does want to be able to express himself clearly and convincingly. As you get older you will find that some engineers are noted for the clearness of their writings, while others, who perhaps have just as good ideas, fail to convince the reader because of the slovenly way in which they are presented. It ought really to be a matter of pride to every young man to be a master of his mother tongue, no matter what his profession. The engineer naturally requires a different style for his work from the lawyer or the theologian; but a good style can be acquired in the general way. The head of your department here has set you an excellent example in his writings of what an accomplished writer can do when handling an engineering subject.

Do not neglect the study of living foreign languages. Your course includes instruction in them; but I know from sad experience that with too many engineers all acquaintance with these languages ends on graduation. This is a great mistake. While it is true that many of the best works in foreign languages are translated into English, it compels the man who knows no other language than English, to wait frequently several years before he can become acquainted with what has been done, as shown by these publications in foreign languages. Then, too, a great deal of most valuable information never gets beyond the technical

journals and proceedings of learned societies ; so that without a knowledge of the languages he would never become acquainted with them. Of course, it is much easier for some to acquire a facility in foreign languages than for others ; but every young man, by faithful work, and, above all, systematic work, can keep up at least a reading acquaintance sufficient for all his needs. An hour's reading every day, faithfully persevered in, will secure the desired result.

Another thing which is simply an accomplishment, but nevertheless desirable when it may be easily acquired, is to become accustomed to speaking in public, and particularly, to making a decent extemporaneous address. In the meetings of Engineering Societies it frequently happens that the discussion of a paper is more valuable than the paper itself; and as these discussions at the time are, of course, entirely oral, it follows that the benefit to all will be much greater if every speaker has sufficient confidence in himself, and is sufficiently accustomed to talking on his feet to make his remarks clear, concise and logical. You can see that if I had had the opportunities when I was young that you have, I might have saved myself a good deal of trouble on this occasion, because I am compelled to read my remarks to you for the very reason that I never had a chance to acquire this training in public speaking. I believe in all our colleges there are debating societies and other opportunities for acquiring this accomplishment, and I would advise you all to profit by them.

You all want to succeed in your chosen profession. That is a matter of course. To do that I can urge nothing more strongly than to be absolutely faithful in all the work you do. Naturally, when you begin, your work will be comparatively unimportant ; but do not despise or neglect it on that account. It is a most important thing to acquire a habit of honest, painstaking work, no matter what you have in hand. We all know the old adage that what is worth doing at all is worth doing well ; and while that should not be carried to the ridiculous extreme of using polished work where it is to go under ground, it is very true for the great majority of things. I have come across young men of great ability who nevertheless could not be entrusted with certain kinds of work, for the reason that they were careless and superficial, and it was impossible to rely on what they did until it had been checked by some one else. There are often times when work has to be done in a hurry and when there can be no revision ; and the man who has accustomed himself to being exact and faithful

in all his work is then just the man for the place. And I tell you from my personal experience that I become extremely fond of men of that kind, who, time and again, have rendered me most valuable service, and enabled me to accomplish results which would have been impossible but for this habit of faithful and conscientious work. I know of one conspicuous failure, where a young man started out with the greatest promise. He was of unusual ability and had had a splendid technical education; but he had what is commonly called "the big head." He thought his life was a failure because he had not made some great discovery or great invention. As a matter of fact, his life was a failure, but not for the reason he assigned. It was simply because he neglected the work which lay right at hand, and was unwilling to go through the preliminary drudgery which would have put him in shape perhaps to have been of great benefit to the profession. Do not make any such mistake as this; it will ruin your whole life.

On the other hand, do not be afraid to assume responsibility. I do not mean by this that you are to rush in and agree to do work for which you know you are incompetent. But when the opportunity comes to do work for which you really know you are as competent as any man of your age, do not hesitate to accept it. You may make mistakes. We all do. The only people who do not make mistakes are those who never try to do anything. But when you are thoroughly grounded in the principles of your profession and have had reasonable experience, your mistakes, if you do make any, should only be those into which any one else would be liable to fall, and for such mistakes there is always forgiveness.

In this connection it may be interesting for me to give you a bit of personal experience, as showing how, when one takes the responsibility, he is sometimes rewarded even in an unexpected way. You have all heard of the recent trial of the triple screw cruiser Columbia of our Navy, the fastest vessel in the world. When the Columbia was designed, it was necessary, in order that she should attain her high speed, that she should have the most powerful engines which had ever been designed, and after a careful study of the case I decided to use three screws for driving the vessel. This was not a new thing, because triple screws had been used before, and had been in some cases successful. I had studied the problem very carefully, and I believed that this was the proper solution of the case. Notwithstanding this, however, many friends of great professional attainment urged me to adopt

another plan, for the reason that they regarded this use of three screws as largely experimental. I felt that the only experiment was in doing on a very large scale what had already been successful on a smaller one, and I was willing to accept the responsibility. What has been the result? The Columbia has proved the fastest vessel in the world; and it has not only been a professional triumph for me, but it has given our Navy and our country the satisfaction of knowing that other countries must now copy us. The unexpected reward of which I have spoken comes in this way: I did not anticipate, when I decided to use three screws, that there would be any advantage, in the way of greater efficiency of populsion, over using twin screws. But the results of the trial have shown that triple screws are actually more economical for propulsion than twins; so that you see my willingness to accept responsibility has been productive of actual benefit.

Finally, I want to remind you that you belong to one of the greatest of the professions. I fear that in times past all engineers have not sufficiently realized the importance of this point. Every man who is a competent engineer ought to feel very proud of the privilege of belonging to this great profession. The progress of the world is due to our profession more than to any other. The recent wonderful exhibition at Chicago was an engineering triumph, and any thoughtful observer must have realized that but for engineering such an exposition would have been absolutely impossible.

Always conduct yourself so that your work will be a credit to the profession of which you are a member; because the glory of the whole is merely the aggregate of that of the units. In this connection it is important and flattering to remember that engineers are frequently called upon to act in the capacity of judges. You are the ones who are to say whether some magnificent work is satisfactory or not. Nobody but the engineer is capable of doing this; and it is a splendid tribute to the engineer's ability and rectitude that the laymen have this implicit confidence in his judgment.

You will notice that a great deal of what I have said relates rather to your work as an engineer after graduation than to your work as a student; but I have believed that what I have had to say would be of more value to you in that way.

I thank you all for the attention with which you have listened to me, and I wish you all every success when you start out in your professional career.

AN ELECTRICAL DEVICE FOR STEAM ENGINE INDICATORS.*

BY D. A. MASON, '94 AND W. B. GREGORY, '94.

When making a test of a compound or triple expansion engine, or an engine where the load is continually varying, as in street railway practice, it is desirable to obtain cards from each of the indicators on the engine at the same instant, and usually for only a single revolution.

To obtain some device by which this could be accomplished was the object of some experiments recently conducted by the writers.

In making the experiments an arrangement partly completed by the late George P. Witherbee was used. It consists of two electric magnets *m m* clamped to the arm of the indicator and held in place by a thumb screw on the bottom (this screw not being shown in the cut.)

The amature *a* is fastened with a screw at *b*, where the handle, by which the pencil is pressed against the drum is ordinarily placed.

By completing the electrical circuit through the coils on the magnets, the armature is drawn up against the pole faces of the magnets and the pencil-point pressed against the drum. When the indicator is not in use the electrical circuit is broken and the pencil is held off the drum by means of the spring *s*, the tension of which is easily adjusted by means of a small thumb screw.

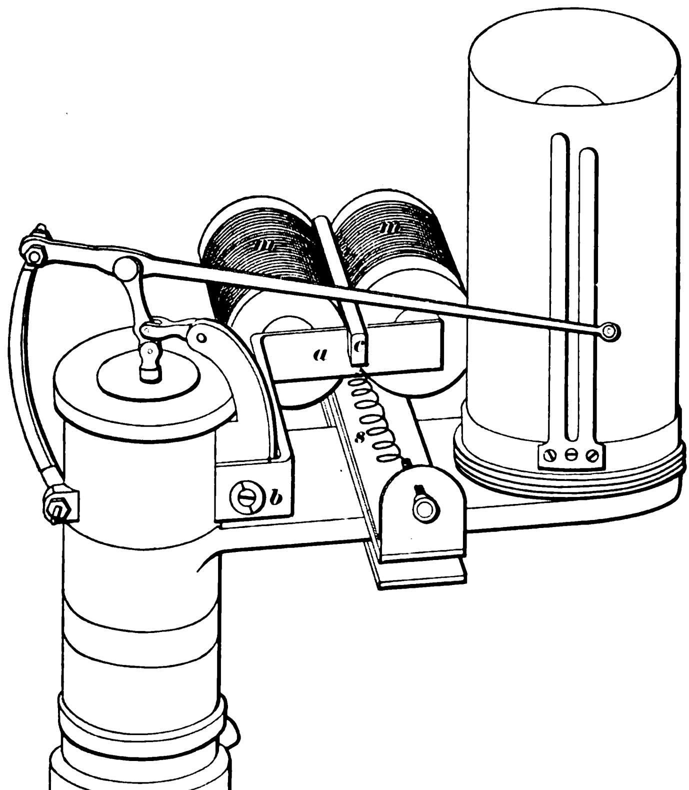
The stop *c* was used to prevent the spring from drawing the armature too far away from the magnets.

The device used for making contact for only a single revolution of the engine consisted of a small cylindrical rod of brass, with a hard steel point, revolving in a small wooden box. Hard rubber tubes were fitted tightly over the brass; but at the center of the rod, the brass was left for a short distance the same diameter as the outside of the rubber tubes. Screw threads were cut on the rubber and brass, the pitch adopted being just equal to the width of the piece of brass left at the center of the rod.

In using the apparatus the steel point of the rod is inserted into the end of the engine shaft, similar to a speed indicator. A wire makes electrical connection from one terminal of a battery to the revolving brass rod. The other terminal of the battery is connected with the solonoids of the electro-magnets, and they in

* Work in connection with the course in Consulting Engineering.

turn with a pointer held in the hand of the operator. He places this pointer in the thread on the rubber-covered brass rod, and as the pointer travels along, due to the revolving of the rod, it passes over the uncovered part. As it does so it completes the electrical circuit and the pencil is pressed on the indicator paper through just one revolution of the engine.



Indicator Equipped with Device.

The device was used by the writers in connection with a Crosby indicator, on a number of engines in the Mechanical Laboratory, and excellent results obtained. From the straight line engine, running at 300 revolutions per minute, perfect cards were taken.

The magnets should be well protected from moisture to prevent short circuiting through the insulation, and the attachment to the indicator well and substantially built, with as high a grade of work on the electrical arrangement as is ordinarily put on the indicator.

BURNING WASTE COAL.*

BY ECKLEY B. COXE, PREST. AM. SOC. MECH. ENG.

In getting power from coal there are three separate and distinct factors to be considered: (1) the furnace, (2) the boiler and (3) the engine; these must be kept independent and the faults or merits of one are not to be attributed to another. The function of the furnace is to convert as large a part of the combustible material as possible into CO_2; if it fails it is because too much carbon has gone up the chimney as CO or into the ash in an unconsumed state. All that is required of a furnace is that it shall deliver to the boiler a good percentage of the heat confined in the coal.

For complete combustion an excess of oxygen must be present and it is a great question in the economical operation of the furnace as to the proper amount of air to be supplied; since five pounds of air must be introduced to obtain one pound of oxygen, a point is soon reached where the heat derived does not offset the heat necessary to raise the air to the temperature of the stack. The solution of this problem of course depends upon the conditions surrounding the furnace under consideration. Analyses of ash and chimney gases will give all information required to ascertain the value of the furnace.

The second factor, the boiler, can well be likened to a sponge; its function is to absorb from the heated gases all the heat possible and transfer it to the water. The heat of the steam depends upon the temperature of entering and leaving gases, which in turn depend upon the position of heating and absorbing surfaces; if the initial and final temperatures of the gases and the amount of coal burned are known, the evaporation can be computed.

Rating a boiler by its horse power is very unsatisfactory, in fact, on account of the diversity of conditions which may accompany a boiler test, and often because of the willful misrepresentation of boiler makers, the "horse power" of a boiler has become a meaningless term. Makers cannot be made to furnish a boiler of a certain horse power unless the definition of a horse power is constant. The purchaser of a boiler should know how and by whom it has been built, also how it is going to work under *difficult* conditions. The horse power obtained from the boiler will depend upon furnace and engine, and the makers have rated it

*Abstract of a lecture delivered before Sibley College.

according to its performance under the best conditions of these two factors and quality of coal.

The influence of the amount of unconsumed carbon present in the ash upon the waste, is shown by the formula, $1 - \frac{bx}{c}$ = per cent of carbon actually utilized, where x = ratio of unconsumed portion of ash to consumed portion, c = amount of carbon in coal, and b = amount of ash in coal. As an illustration apply this formula to the following data, taken from an actual test.

ANALYSIS OF COAL.			ANALYSIS OF ASH.			
Carbon.	*Ash.*	*Volatile Matter.*	*Carbon.*	*Ash.*	*Volatile Matter.*	*Per Cent. of Carbon actually utilized.*
82	12	6	50	48	2	84.75
82	12	6	10	88	2	98.33
82	12	6	2	96	2	99.7

$$1 - \frac{bx}{c} = 1 - \frac{\frac{50}{48} \cdot 12}{82} = 84.75$$

It is usually the case that when a good grade of coal is used, more attention is given to the matter of waste than when a poor grade is employed, while from the standpoint of economy, the reverse should be true; that is, it is more important that wastes should be reduced when burning the cheaper grades. It is this question of wastes in general, which constitutes one of the chief problems with which the engineer of the present day has to deal. Modern engineers will not be called upon to invent the telephone or the compound engine. It is the practical, every day question of economy which is the paramount consideration influencing the installation and operation of every power plant built to-day. The young engineer should therefore remember that the fundamental duty devolving upon him will be to avoid waste in every possible way; he who knows best how to accomplish this will be the most valuable to his employer. More failures have resulted from lack of economy in the small details than from any other cause; "have a care for the pennies and the pounds will take care of themselves."

Too much emphasis cannot be laid upon the value of honesty to the engineer; a reputation for strict integrity is absolutely essential for success in his profession, and it is this feature which gives to science the honorable position it maintains unchallenged.

LOCOMOTIVE BUILDER'S DRAFTING ROOM SYSTEM.

BY J. S. REID.

The large number and variety of orders received in a locomotive builder's drafting office for locomotives and tenders of different styles and sizes, for duplicate parts, repairs, etc., necessitates the following of some definite system that will ensure the greatest economy in time and labor, a minimum of errors in preparing the bills for ordering materials and standard furnishings from the manufacturers of locomotive specialties outside, and in making the large number of drawings and sketches necessary in producing the different parts of a locomotive and tender, from the boiler and cylinders down to the smallest detail.

The writer will endeavor to explain at least some of the methods pursued at present by most of the leading locomotive builders of this country. We will begin with the order for locomotives and tenders which has been received from the office by the chief draftsman. It has probably been placed by the superintendent of a railroad company, accompanied by blue prints and a specification containing explicit directions and data concerning the style of the engine, its leading dimensions and proportions, such as the diameter of the boiler at the first course, the diameter of the cylinder and stroke of piston, weight of drivers, working steam pressure, etc., etc., all of which must be strictly adhered to by the builders, except where changes advantageous to both parties may be made by mutual arrangement. The draftsman selected by the chief to have charge of the making of the drawings for this order is called a main draftsman, from the fact that he makes the main drawings of the engine and is held responsible, not only for them, but also for all detail drawing connected therewith. He is given the specifications and any special instructions that may be necessary, when he at once begins to find out all he can from the specifications concerning the boiler. When that is done he makes a freehand sketch of it, unless a blue print fully dimensioned has been sent by the railroad company. He is now ready to make the scale drawings of the elevation and cross sections. These are usually made to a scale of 2″ to 1 foot, upon two sheets of paper mounted on cloth, one for the longitudinal elevation, the other for cross sections and end views.

As soon as the necessary outline of the different views of the boiler has been accurately laid down, the next thing to be done

is to get out the boiler bill. This consists of a list of all the plates used in the construction of the boiler, which has been properly developed, carefully measured, and an allowance added for trimming. When we state that it is often six weeks from the date of ordering the boiler bill until the plates are delivered in the boiler shop, it will be seen how important it is to get this bill made out and sent off as soon as possible.

For an ordinary eight wheel passenger engine, the boiler bill is written out in detail on a sheet of foolscap about as follows :

BOILER BILL, NO. 997.

Engs. 1321–1330, Dec. 1, 1893.

Shts.	*Material.*	*Thick.*	*Length.*	*Width.*	*Name.*
1	Otis Steel,	½″	168½″	62″	1st course.
1	"	½″	171¾″	58″	2d course.
1	"	½″	[Diagram.]*		Top gusset.
1	"	½″	———	—	Lower gusset.
1	"	½″	———	—	Crown.
2	"	½″	———	—	Sides.
1	"	7/16″	[Diagram.]*		Back head.
1	"	⅝″	———	—	Throat.
1	"	½″	———	—	Dome.
1	"	½″	Diameter.		Front tube.
1	Iron,	7/16″	———	—	Smoke box.
1	"	7/16″	———	—	Smoke box extension.
			FIRE BOX.		
1	Otis steel,	⅜″	———	—	Crown.
2	"	5/16″	———	—	Sides.
1	"	5/16″	[Diagram.]*		Door sheet.
1	"	½″	[Diagram.]*		Back tube.
1	Tank iron,	⅜″	———	—	Cyl. saddle liner.
1	" "	⅜″	[Diagram.]*		Back head liner.

When the main draftsman has completed the bill he goes all over his drawing and figuring the second time, and, when *sure* it is correct, he hands it over to the chief draftsman, who, assisted by the foreman boilermaker, compares the drawings with the specification, carefully calculates the sizes of the developed sheets and checks off each item as he finds his figuring corresponds to the main draftsman's work. This extreme care is necessary because a boiler bill is often used to order the material for twenty

*Diagrams of the various parts, showing shapes and dimensions, are made in rubber stamps, and placed on the boiler bills.

and even thirty boilers at a time, and one slight mistake might mean the loss of a large amount of money as well as of precious time. When the main draftsman's work is finally decided to be correct, he takes the bill to the draughting-room bookkeeper, who makes a correct copy of it in a boiler bill book and numbers it. This copy the draftsman compares with the original and makes sure it is correct. We now come to the outside order sheet blank, or store room check.

This sheet has printed upon it the names of all the standard parts of the locomotive and tender, usually ordered outside, such as axles, boiler bill, crank pins, steel crossheads, connecting rods, frames, injectors, oil cups, light iron bill, piston rods, steel tires, tank bill, etc., etc.

The draftsman enters the boiler bill number at the proper place on this sheet, and passes it immediately to the outside order clerk in the counting house, who becomes responsible for its further progress from this point onward. The draftsman next proceeds to draw down on the main drawing the frames, axles, crank pins, piston rods, and everything essential in determining the dimensions of these and other parts of the engine to be ordered outside. While the main draftsman is engaged in this manner with the engine, the chief draftsman has given the work on the tender in charge of a junior draftsman, who is usually a man of some experience and next in succession to the main draftsman. This man makes a drawing of the tender to the specifications on the same size and kind of paper as the main drawing, laying down the tank first and making a tank bill similar to that of the boiler. This is also examined, copied, numbered and entered on the outside order sheet. In ordering the frames, axles, crank pins, connecting rods, tires etc., blue prints are used of a convenient size for mailing. These prints are kept in stock in drawers, divided into compartments to keep the different styles separate. When the draftsman is ready to fill them up, he writes the dimensions in blank places printed in white for that purpose. He then takes it to the bookkeeper, who enters the name of the article and the engine number in a card index book under its proper heading, and gives it the next consecutive number. This number the draftsman enters in the outside order sheet as in the case of the boiler bill. When all the principal parts of the engine and tender have been ordered, the draftsman's attention is next directed to the light iron bill.

Some of the items of this bill are the ash pan sides and bottom,

ash pan front and back dampers, the cab front and side sheets, guide yoke sheets and waist sheets, front bumper plate, tender shoveling iron, etc., etc. The bill when complete is numbered and ordered by number on the outside order sheet in like manner to the other bills. While working on the outside orders, the draftsman can also direct the making of the working drawings, for the shop, of the parts he has already laid down on the main drawing for this purpose. He has assigned to him, by the chief, an assistant draftsman, sometimes called a detail draftsman. When a large number of working drawings require to be made, as is sometimes necessary, two assistants can be kept busy as the main drawing progresses. The working drawings made first are those for which new patterns require to be made, or old ones changed; and, as the cylinder is the most important casting on the locomotive, and takes a long time in making, if a new pattern should be necessary, the cylinder card is usually made first. The cards upon which the working drawings are made are of 3 sizes, viz, 9″ × 12″, 12″ × 18″ and 18″ × 24″, of heavy card board mounted with strong Irish linen paper. The drawings on these cards have the sections tinted with the conventional colors for the different materials, and are very clear and easily read.

The cylinder is usually drawn on the medium size card to a scale of 2″ to 1 foot, and when finished is handed to the main draftsman to be examined. This he does very carefully, checking off each dimension as he finds it correct, and, when satisfied that all the dimensions necessary for the pattern maker to make the pattern are given, and everything is all right, he is ready to order it made. It might be well to state here that sometimes the different views of the cylinder are traced from the main drawing and fully dimensioned, and the tracing used in the pattern shop, while the cylinder card, which may be made later, carries only figures enough to finish the casting in the machine shop. When the engine number, for which the cylinder card has been made, is duly entered in the card index book and the card numbered, the draftsman next writes an order, on a sheet of his scribbling pad, to the bookkeeper as follows:

DEC. 1, 1893.

MR. CHUBB:

Please send order to Mr. Wood to make cyl. pattern No. 2537 as soon as possible, to suit Cyl. card No. 57 for Engines Nos. 1321–1330.

BERT. ANDERSON.

This notice, together with the card, is left with the bookkeeper, who writes the order on a printed blank, the order being transferred at the same time to a general drafting room shop order book. While this is being done the office boy has varnished the card with white shellac varnish, which is quite transparent and drys in a very few minutes. The bookkeeper then sends the boy with the order, order book, and card to the foreman pattern maker, who signs the book and retains the order and card. The boy returns the book to the office.

Before sending any cards into the shop, the draftsman has made for him a set of shop sheets bound together with brown paper covers and iron binders. These sheets consist of a card record, a brass sheet, an iron casting sheet, and a forging sheet. The card record has printed upon it the names of all the parts of the locomotive and tender, for which working drawings on cards are made to be used in the shops. Opposite each name there is a column for the card number, and, as each card is finished, its number is entered on the card record. In connection with the card record there are sheets called job sheets, named with the name of the job to which they belong, as the link job, the guide job, the rod job, etc., etc. Each job sheet has printed on it the card names of the different articles made by that job, and, as the cards are finished and their number entered on the card record, the boy is sent for the job sheet to which the article belongs. The card number is also entered on it and the man in charge of the job notified.

The brass sheet which comes next to the card record is similar to the latter, except that, when filled up, it carries only numbers of cards of articles, the whole or part of which is made of brass. As the brass castings are comparatively few, the foreman of the brass shop orders his castings from the brass foundry, by the pattern numbers given on the cards, thus saving a special sheet for brass castings.

We come now to the iron casting sheet. The names of all the iron castings used on the locomotive and tender are printed on this sheet with a space provided for the pattern number of each. When laying down the iron casting details of the engine on the main drawing, the draftsman collects all the drawings of the details, for which patterns have already been made, of all styles and sizes, and adapts them, when possible, to his needs. It sometimes happens that, to use a certain pattern a slight change is necessary. In ordering this change made in the pat-

tern shop, the draftsman has a new style drawn on the original card embodying the alteration, and marks it Style 2. A table is also made on the same card as follows :

CARD.	PATTERN.	STYLE.
No. 47,	No. 1476	No. 1.
No. 51,	No. 1476 Alt.	NO. 2.

The notice to the book-keeper is made to read :

Please send order to Mr. Wood to change ——— Pattern, No. 1476 to suit Style 2, Card No. 51, for Engs. 1321–1330.

B. A.

Before this change can be made on an old card, the varnish has tô be washed off with alcohol and then rubbed dry with cotton waste. When the change is made, it is revarnished and sent with the order to the pattern maker.

A large number of small castings are common to nearly all styles and sizes of locomotives. The pattern numbers of such can be entered in the casting sheet at the draftsman's convenience.

THE FORGING SHEET.

The forgings of a locomotive and tender are made from sketches drawn on strong drawing paper, cut to the following sizes, 5″x7″, 5″x14″ and sometimes 10″x14″. These sketches when finished are recorded in a Forging Book in a similar manner to the Iron Casting pattern drawing, given the next consecutive number and traced on sheets of tracing cloth, large enough to contain 4 of the small size, 2 of the medium, or 1 of the largest. Each sheet of tracings is varnished and placed with others between heavy card board covers bound with leather and held together at one side with bolts and nuts. There are usually about one hundred sheets in a book of tracings. These books, which never leave the drafting room, and when not in use, are always to be found on a rack in a convenient part of the room are often consulted by the draftsman to find sketches of forgings suitable for his engine. These new sketches are made by junior draftsman on sheets of brown detail drawing paper of a size large enough to make four of the small size sketches. When correct they are signed with the initials of the

main draftsman, entered by number on the engine forging sheet, and sent to the foreman blacksmith, with a notice from the bookkeeper stating that this forging has been ordered for engines 1321-1330. A duplicate of this order in the general shop order book, as explained for the cylinder card, is signed by the foreman. Should anything happen to the sketch, after having been delivered to the blacksmith, and the forging fail to be made in proper time, the foreman's receipt in the order book relieves the draftsman of all responsibility in the matter.

BOOK OF DRAWINGS.

Duplicate drawings of a large number of the more important details are made on white drawing paper, cut to about 16″ x 20″, and when finished, mounted in books similar to the forgings sketch tracings. These drawings are for use in the drafting room when the cards are in the shop. When a job in the shop is finished and proved by the general foreman, the foreman of the job is then expected to send the card he used back to the drawing room, and see that the card boy gives him credit for it. All cards are kept in a rack divided into compartments, each compartment containing a group of the details of the locomotive and tender. These divisions all number from one upward and in a card rack index book the names of all the cards in the rack are printed alphabetically; and opposite the names is given the numbers of the cards, the engines they were made for, and the compartment number where they may be found. In each compartment is placed a ruled slate, and it is the duty of the card boy, when he takes a card to the shop, to charge it by name and number on this slate to the foreman, who receives it, and, when the card is returned, credit is given by cancelling the entry charge on the slate; so that, should a certain card be called for, the card boy first examines the slate of the pocket it belongs in, and, if not charged, then it ought to be found in its place in the rack. When the store room check, or outside order sheet is filled up, the cards and sketches all made, the card record, brass sheet, casting sheet and forging sheet filled up and ordered, except for an occasional tour through the shops to see that everything in connection with engines 1321–1330 is being produced as designed, and according to specifications, the main draftsman's special attention may now be directed to any other work he may have on hand; but not until the engine is completed and under steam on the track, is the draftsman relieved of certain responsibility.

In the foregoing, an endeavor has been made to describe the drafting room system in force in most of the leading locomotive building shops in this country, emanating, we believe, in the first place from the Baldwin Locomotive Works, Philadelphia, Pa. Although somewhat incomplete, for the lack of samples of books, blank sheets, cards, drawings, blue print, blanks etc., etc., yet this explains substantially the system in successful use at the present time.

MECHANICAL REFIGERATION—ARTICLE II.

BY R. C. CARPENTER.

In the first article in this series the underlying principles were considered and a few of the processes employed in refrigeration were described in a general way. In this article it is proposed to consider the compression system of refrigeration as practiced by one of the oldest and best known firms in this business.

It should be noted in the beginning that there are two distinct objects of Mechanical Refrigeration, one of which is the maintenance of a low temperature, for preservation of meats, fruits, etc., the other the production of ice. The process of obtaining the low temperature is usually termed *refrigeration*, that of making ice is called *ice making*. For these two purposes, as will be described later, the machines are worked under different ranges of temperature, and the final stages in the operation are quite different, but the actual processes for lowering the temperature are essentially the same. Technically the capacity of a plant for *refrigeration* and for *ice making*, is defined by the same term, but which does not, however, have exactly the same meaning.

The *capacity* of a machine for refrigeration or ice making is expressed in tons of ice for each twenty-four hours; in the first place the term has reference to the heat transferred from lower to higher temperature, compared with that absorbed in changing one pound of water at 32° F. into ice; in the latter place the term refers to the actual capacity of the machine to make ice. The actual operation of ice making, involves not only freezing but also the lowering of temperature of the water to 32°, and various other losses which do not enter into consideration in the question of cooling. These two capacities have been defined in the case of refrigeration as equivalent to *ice melting*, and in the case of

forming ice to *ice making*. For small machines the heat equivalent of melting capacity is double that of the freezing capacity, for large machines the melting capacity is about 1.75 to 1.5, the freezing capacity due to reduction of the losses in the machine.

This of course is a general distinction and applies to all forms and classes of machines.

The classification of various types of refrigerating machines was given in the last article, page 222. The system of refrigeration to be described in this article is that of an Ammonia machine of the compression type.

GENERAL PROPERTIES OF THE WORKING SUBSTANCE.

It was shown in Article I that any working substance might be used in a refrigerating machine of the compression type.

The fundamental expression of efficiency is in every case, see equation (7).

$$E = \frac{K_1}{A(W_c - W_e)} \qquad (7)$$

In the above expression K is the heat transferred and $A\ (W_c - W_e)$ is the net work, expressed in B. T. U., required to operate the machine.

Even a steam engine, run backward or as a compressor, with steam as a working substance would convey heat from the lower to the higher temperature, at the expense of the net work of compression. In this case, however, the lower limit of temperature could not be less than that of the freezing point of water in any working machine, although one can easily conceive that the work of compression might be sufficient to raise the water to any desired temperature, from any given temperature. In either case, when expansion occurred, an amount of heat equivalent to the latent heat of liquifaction would be absorbed from the surrounding medium.

While steam or vapor of water has a very high latent heat, it becomes solid at a comparatively high temperature (32° F.) and consequently would not be well suited for use in a refrigerating machine.

In a pressure below that of the atmosphere, considerable vapor is given off, and practical ice making machines have been built to work under such conditions. These machines are known as *water vapor* or vacuum machines.

If one were to consider in an abstract manner the properties

desirable in a liquid to be used for refrigeration purposes, he would note :

First: Latent heat of vaporization large ; this will permit the use of a small amount of working substance, since the capacity of a given weight to transfer heat is proportional to this quantity.

Second: Freezing point low ; as its capacity to absorb heat is a function of difference of temperature, the lower the temperature at which a given substance will remain liquid, the greater the capacity of a given weight, and also the lower the temperature which can be attained. It is hardly necessary to mention that a solid body can not be pumped and that as soon as it solidifies it becomes useless.

Third: Considerable change in temperature for moderate increase of pressure. It is evidently desirable to obtain liquids with greatest latent heat, and with lowest freezing points ; in addition to that, commercial considerations render it necessary that the liquid shall be reasonable in cost and shall be one that will not attack or destroy the machinery used.

Every consideration mentioned favors the use of anhydrous ammonia. This material is produced as a waste product in various industries, in an impure form and it needs only to be purified and separated from water to fit it for refrigeration purposes.

The material exerts no corrosive action on iron and for this reason does not affect in any degree the ordinary machinery for conveying or compressing it.

It will, however, attack brass or copper and must be kept from contact with these metals.

Its important properties are given in the following table :

At atmospheric pressure, boiling point is 28.6 F. Weight, at 32° F. combined with water is 0.6364, or 39.73 pounds per cubic foot, or 5.3 pounds per gallon. Specific heat is 0.50836. Latent heat at 32° F. is about 560 B. T. U.

The following table giving the principal properties for each 10 degrees of temperature on the Fahrenheit scale, is taken from Professor Wood's Thermodynamics.

SATURATED AMMONIA.

Deg. F.	Pressure absolute per sq. inch.	Total Latent heat. r.	Extern'l Latent heat. a p w	Internal Latent heat. S.	Vol. of 1 pound of vapor cu. ft.	Vol. of 1 pound of liquid cu. ft.	Weight of 1 cu. ft. in lbs.
−40	10.69	579.67	48.25	531.42	24.38	.0234	.0411
−30	14.13	573.69	48.85	524.84	18.67	.0237	.0535
−20	18.45	567.67	49.44	518.23	14 48	.0240	.0690
−10	23.77	561.61	50.05	511.56	11.36	.0243	.0880
0	30.37	555.5	51.38	504.12	9.14	.0246	.1094
10	38.55	549.4	51.13	498.22	7.20	.0249	.1381
20	47.95	543.15	51.65	491.50	5.82	.0252	.1721
30	59.41	536.92	52.02	484.90	4.73	.0254	.2111
40	73.00	530.63	52.42	478.21	3.88	.0257	.2577
50	88.96	524.3	52.82	471.44	3.21	.0260	.3115
60	107.60	517.93	53.21	464.76	2.67	.0265	.3745
70	129.21	511.52	53.67	457.95	2.24	.0268	.4664
80	154.11	504.66	53.96	450.75	1.89	.0272	.5291
90	182.8	498.11	54.28	443.70	1.61	.0274	.6211
100	215.14	491.5	54.54	437.35	1.36	.0279	.7356

THE DE LA VERGNE REFRIGERATING MACHINE.

This is an ammonia compression machine of the type already described. The general principles of operation have already been stated; they are quite fully illustrated in Plate I.

For this case we have the compression pump *A*, which is operated by a steam engine *R*, although any other source of power might have been used. Gaseous ammonia is received in the suction pipe *B*, whence it is compressed into a comparatively small volume.

In this system the clearances of the compressor are filled with oil by the action of a small pump, shown attached to the frame, which maintains a constant amount in the cylinder. More or less of this oil is removed with the compressed gas which is discharged through the pipe *C* into a tank or reservoir *D*. In this tank the greater portion of the oil separates from the ammonia and is drawn from the bottom for future use. The gas which has been heated by the compression passes from the reservoir to a series of coils *F*, which either are immersed in water or are arranged so as to receive a constant drip from falling water. In this series of coils, termed the condenser, the hot gas under pressure is cooled and liquefied. From the condenser the liquid ammonia passes through a storage tank, thence through another separator *K* to remove the last traces of oil, thence through an expansion cock to an *expansion* coil.

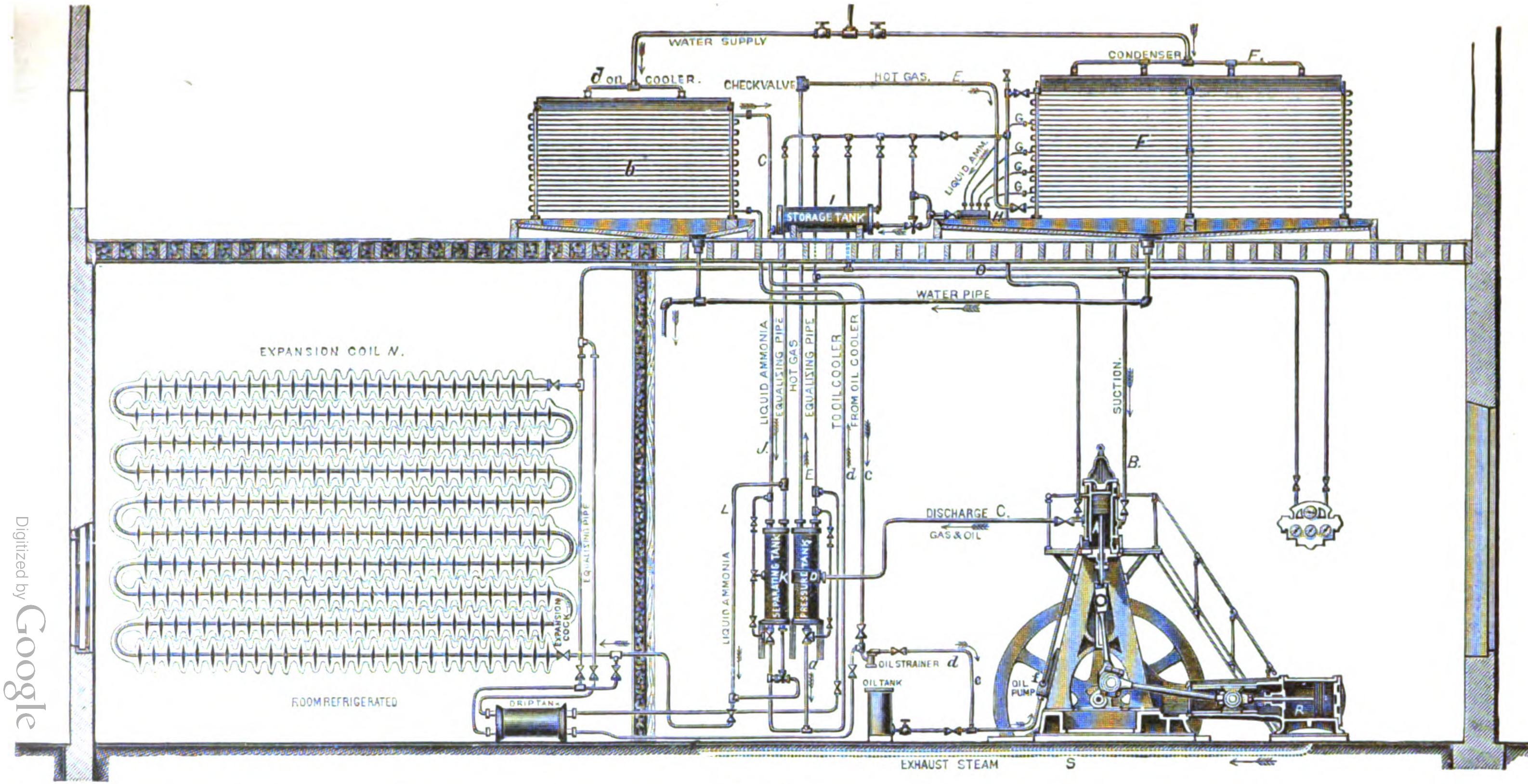

WATER SUPPLY
CONDENSER
F
F
d OIL COOLER.
b
CHECKVALVE
HOT GAS. E.
C
STORAGE TANK
I
LIQUID AMM.
G
G
G
G
G
H
O
WATER PIPE
EXPANSION COIL N.
LIQUID AMMONIA
EQUALISING PIPE
HOT GAS
EQUALISING PIPE
TO OIL COOLER
FROM OIL COOLER
SUCTION.
B.
J.
E
d
c
L
DISCHARGE C.
GAS & OIL
EQUALISING PIPE
LIQUID AMMONIA
SEPARATING TANK
K
PRESSURE TANK
D
EXPANSION COCK
OIL STRAINER
d
OIL TANK
c
OIL PUMP
f
R
ROOM REFRIGERATED
DRIPTANK
EXHAUST STEAM
S

PLATE I.

In this latter coil the expansion takes place and an amount of heat sufficient to evaporate the ammonia is absorbed from the surrounding air. As the ammonia boils under atmospheric pressure at about 28.6 degrees below zero F. this operation will take place at a very low temperature. In other words were the pressure reduced to that of the atmosphere in the expansion coil, it might be possible to produce a temperature 28° below zero.

As shown in Plate I the ammonia circulates in pipes which are exposed directly to the air of the room which is to be cooled. The surface of these pipes are increased to a great extent by the addition of metallic disks, which have the effect of largely extending the cooling surface at small expense.

For refrigeration purposes, in some cases the expansion coil is immersed in a tank of brine, and the brine is reduced to a low temperature and circulated directly in the rooms to be cooled. In the system shown the oil is cooled and returned from the various separating tanks to the oil pump, thence supplied to the compressor as required. One of the most interesting features of this system is the method of supplying and maintaining the oil in the compressor. This is illustrated very well in the sectional views Plate 2 and Plate 3.

In Plate 2 is shown the sectional view of the single-acting compressor, which is practically identical with the one in the refrigerating machine in Sibley College.

In this machine oil is supplied at the bottom through a small pipe, gas is supplied through the pipe at the left near the bottom, lifting the check valve as it enters.

The gas enters the cylinder through oil in the bottom. Sufficient oil is maintained in the cylinder to fill the clearances and to form a seal over the check valve. As the piston descends the gas passes through the check valve and when the piston moves upward the gas is compressed and finally discharged at the required pressure, through the proper valves, into the system.

The oil seal is maintained over the piston and all the valves in order to prevent leakage and to completely and effectively fill the clearance space. The oil is discharged after the gas.

It may be remarked that the effect of large clearance spaces, is to reduce the efficiency of the compresser very much, as the gas filling the clearance space expands or is compressed, due to the motion of the piston, and prevents the admission of a full supply. It consequently reduces the capacity to a great extent. It is essential to efficient compression to have small clearances.

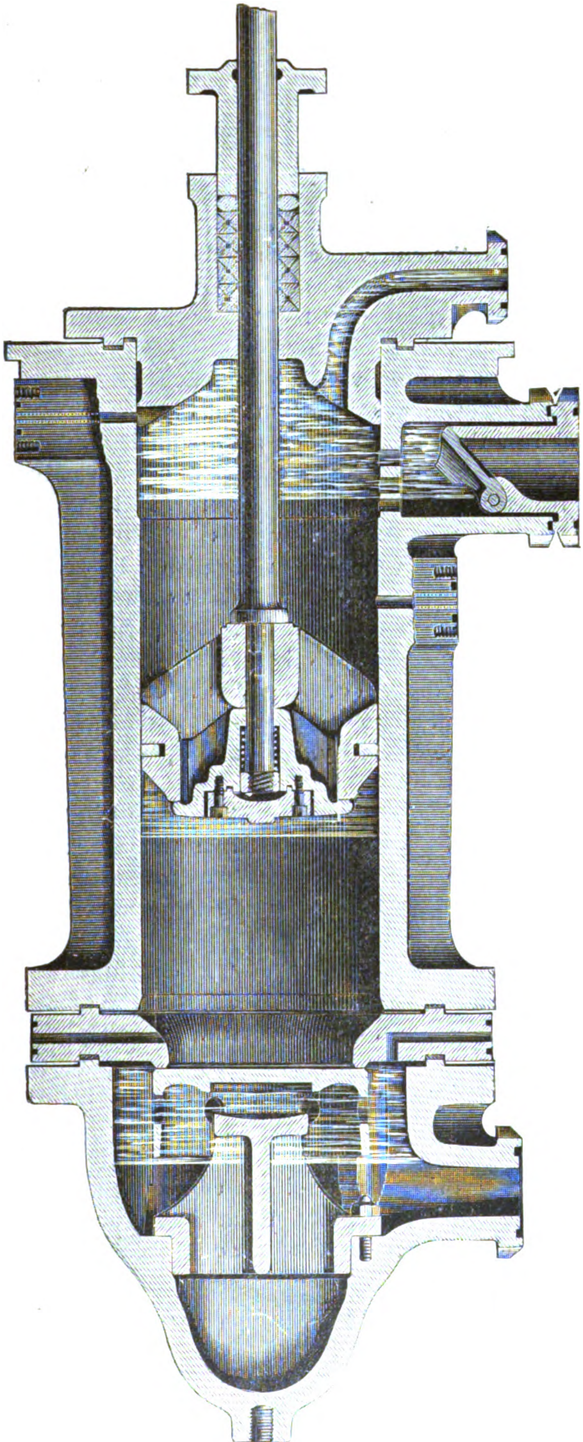


PLATE II.

The double acting compressor is shown in Plate 3. This has a special ingenious construction in order to maintain an oil seal both at the top and bottom of the cylinder, and to prevent the discharge of the oil, before all the gas has been driven out.

By referring to the cut, we see that the suction gas is received near the center of the cylinder at the opening shown on the left.

It can enter the cylinder at the top or the bottom, flowing by the spring check-valves. When entering at the top it is discharged through the top valve very much as in the preceding case. When entering at the bottom it is discharged on the downward stroke of the piston through horizontally moving poppet valves. It discharges through the upper or lower valve until the piston in its descent covers the upper part. It then passes up into the body of the piston, through valves held to their seat with a somewhat stiffer spring, and when the piston has descended the proper distance, a side opening is brought on a level with the upper part, in the body of the cylinder, thus permitting the gas to escape without disturbing the oil on the bottom head of the cylinder. The farther descent of the piston forces the oil out after the gas. This operation prevents the re-expansion which would absorb heat and reduce efficiency, due to the passage of oil with the gas.

The function of the oil pump is quite different in the newer and older forms of the De La Vergne refrigerating machines. In the old machines, the pressure was entirely removed from the oil after it had been separated from the ammonia and a powerful force pump was required to force it into the compressor. In the new system, see Fig. 1, the oil is kept under the pressure due to that of the compressed ammonia after separation, so that the office of a pump corresponds to that of a meter or valve, which simply opens to let in the proper supply at each stroke or as often as required. The compressor is usually driven by an engine connected as shown in the Frontispiece.

The Sibley College compressor is of the single acting type as shown in Plate 2, driven by a belt instead of by an engine. The upper portion of the piston has a flat face as shown in Plate 3, although its principle and method of action is as described for the single acting compressor. The oil is under pressure and admitted by a valve which is opened once in ten strokes by proper mechanism.

The expansion cock or valve is, in the older systems, a cock or valve arranged so that it can be opened very gradually and a

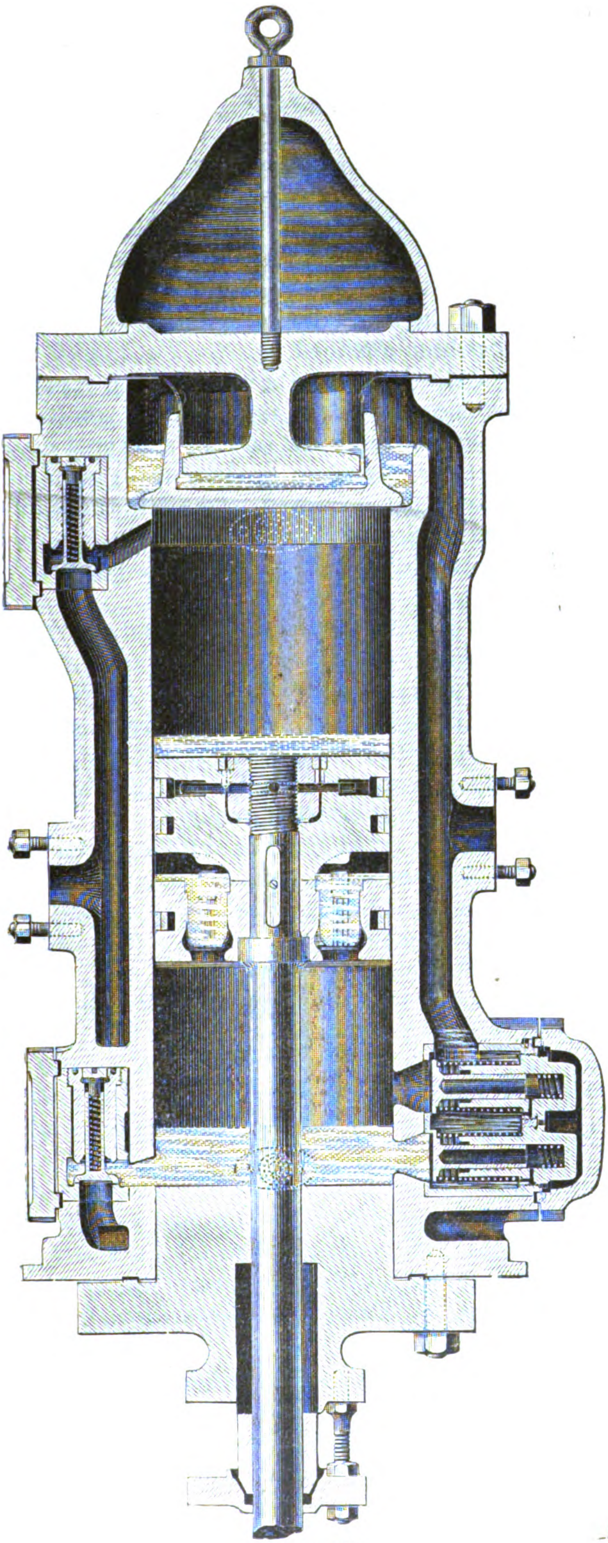


PLATE III.

definite amount, by means of a hand wheel. Its location will be seen in Plate I to be near the expansion coil. Its office is to permit the introduction, of the proper amount of liquid ammonia into the expansion coil when it expands into gaseous ammonia. It is ordinarily merely a device for throttling the pressure, which is regulated by hand until the required pressure and temperature in the expansion coil has been obtained.

In the Sibley College machine a new form of expansion cock is introduced, by means of which the machine admits automatically a given amount of ammonia into the system at each stroke. This amount can be regulated to produce any given back pressure or temperature that is desired. The less the ammonia admitted into the expansion coils, the less the back pressure and the lower the temperature, these results corresponding with the table already given.

The mechanism for this consists of a revolving piston, into which a cavity is bored, which has a capacity for a given amount of ammonia. This cavity, by revolution of the piston, is alternately brought over a port supplying liquid ammonia and over a port discharging into the expansion coil.

When in one position it will fill up with the liqud ammonia and in the other position it will be discharged.

Thus each revolution takes into the system a volume of liquid ammonia, equal to the cubic contents of the cavity in the piston, diminished by the same volume of gaseous or expanded ammonia. It, in effect, becomes a meter by means of which we can accurately compute the ammonia used by the machine.

By removing the piston and inserting annular plugs or washers, the cavity can be varied to produce any given back pressure.

The best back pressure to be maintained will depend upon the character of the refrigeration. The lower the back pressure the lower the temperature and the less ammonia that is used by the system.

The amount of refrigeration is proportional to the amount of work done in compressing the ammonia gas, less the heat losses which occur during compression. Both the work and heat losses would increase with the range of pressure, so that a certain range of pressures for a given sized compressor will no doubt be most economical.

In considering the diagrams from such machines, we note that a low back-pressure corresponds to an early cut-off, and a high back-pressure to a late cut-off in the steam engine. It can readi-

ly be seen that a diagram having a high back-pressure may have a greater area than one having low back-pressure, in which case the work done would be greater, although the range of pressures would not be so great. From this it is to be seen that the capacity of the machine may be greater with a high than with a low back pressure, and is in fact proportional to the amount of ammonia used per stroke.

In general the best work is performed with a back pressure of 20 to 40 pounds above the atmosphere, as the temperature at this pressure, causes less loss of capacity from ice on the pipes than a lower temperature. It should be noted that a covering of ice or frost tends to materially lessen the power of the material to absorb heat. thus in a marked degree reducing the capacity of the system.

The following table is useful in computing the heat transfer in case brine is used, as the agent for refrigeration.

SPECIFIC HEAT OF BRINE.

Percentage of Salt by weight.	Percentage of Water by weight.	Specific Heat.	Degrees on Salometer, 60° F.	Freezing point, Degrees F.
0	100	1.000	0	32.0
1	99	0.992	4	30.5
5	95	0.960	20	25.2
10	90	0.892	40	18.7
15	85	0.855	60	12.2
20	80	0.829	80	6.1
25	75	0.783	100	0.0

The subject of ice making will be taken up and discussed in a later article.

AN IMPROVED METHOD OF CALIBRATING INDICATOR SPRINGS.

BY S. H. BARRACLOUGH AND L. S. MARKS, GRADUATES.

Until within recent years it has been the general custom to calibrate indicator springs cold. The method commonly adopted was to load the spring with dead weights and compare the load with the corresponding movement of the pencil. It has, however, been recognized for some time that a large error is introduced by applying the cold calibration to the reading of the indicator when used to increase steam pressures.

Consequently several methods have been employed to obtain a hot calibration of the springs.

The first of these was by Mr. Porter who was then engaged in the manufacture of the original Richards indicator. He employed the old method of dead weights and directed a jet of steam upon the spring under calibration.

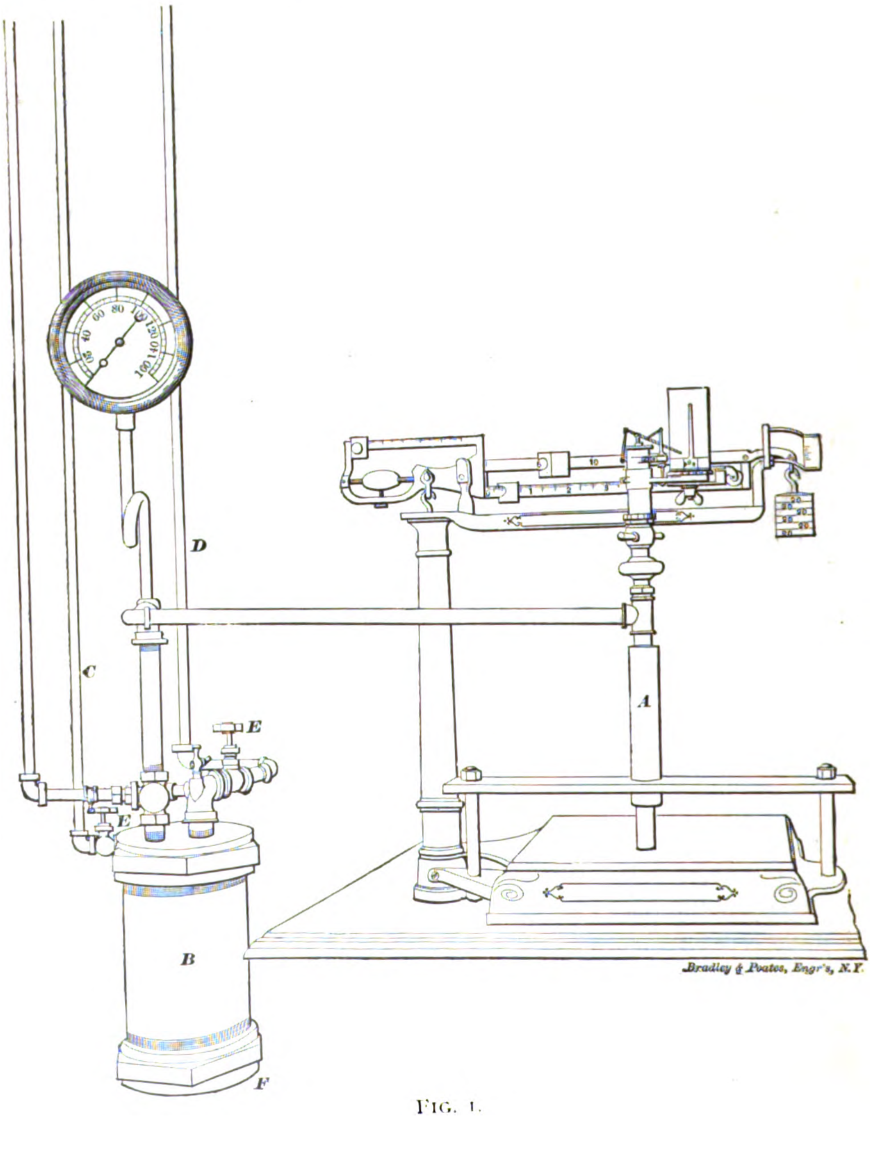


FIG. 1.

A method in extensive use, and one which has been adopted in the U. S. Navy Department, is to compare of the reading of the indicator with the height of a mercury column, both being subjected to the same steam pressure.

It has been found that successive calibrations of the same spring by this method do not give consistent results, a fact which has been explained as due to the existence of pulsations in the column.

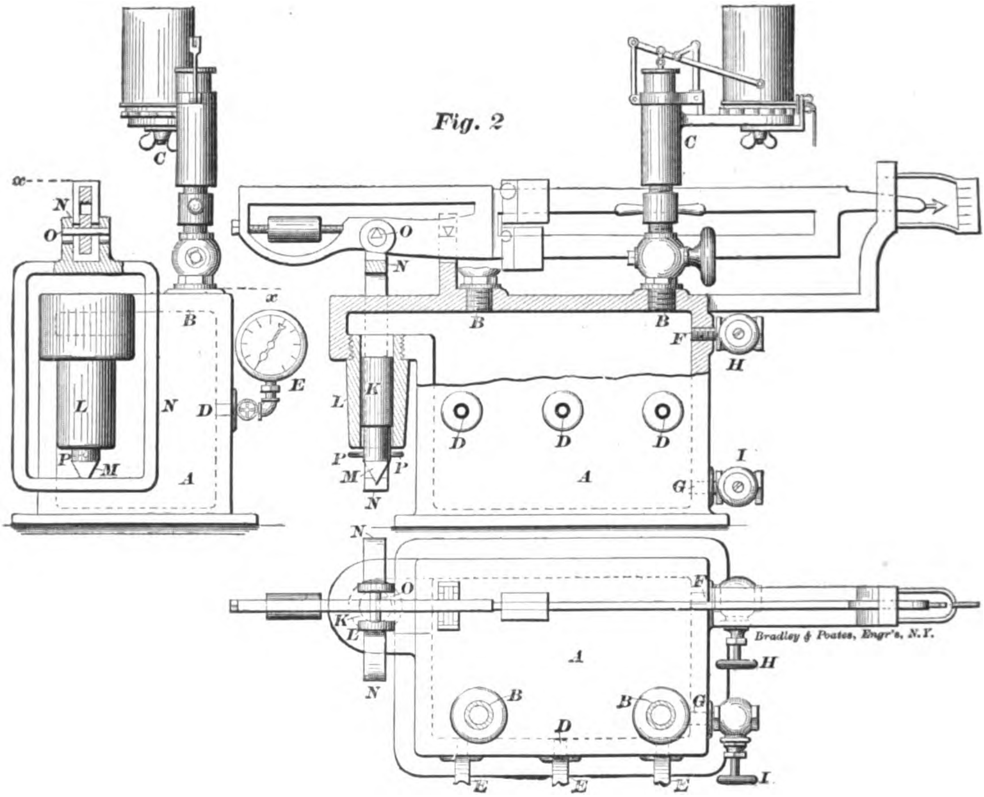
The method which it is the object of this article to describe is one in which the movement of the pencil is compared with the readings of a standardized weighing scale with the same steam pressure acting on both.

The apparatus first used is shown in Fig. 1. The cylinder *A* is screwed onto a cross bar formerly supported above the platform of a standardized weighing scale. A piston working freely in the cylinder rests upon the platform. The indicator to be tested is screwed to the top of the cylinder. Steam is admitted into the space between the piston in *A* and the indicator piston by a pipe leading from the reservoir *B*, the pressure in which is shown by a steam gauge. The reservoir communicates with the boiler by pipe *C* and can also be exhausted into the atmosphere. The pipe is connected with a compressed air reservoir by means of which the indicator can be calibrated at atmospheric temperature if desired.

A more compact and convenient form of the apparatus, designed by Professor Carpenter, is shown in Fig. 2. In this the indicator is screwed directly onto the reservoir *A* and the piston *K* rests upon a yoke *N* through which the pressure is transmitted to the scale beam. The apparatus may also be used for calibrating gauges which are fitted onto the reservoir at *D*. This arrangement is one now in use in the Sibley College laboratories.

The method of using the apparatus is as follows:

Both pistons are first lubricated with cylinder oil and steam is blown through to warm the cylinders. The scale is adjusted to zero reading by moving the counterpoise with the piston resting upon the yoke, the piston being lightly tapped or rotated to prevent any tendency to stick, the same precaution being taken throughout the whole calibration process. Two vertical lines are drawn on the indicator card near the centre. The poise is set at a given load and the steam pressure is allowed slowly to rise by adjusting the inlet and exhaust cocks. At the instant when the pressure has risen so as to make the beam "float" in its midway position a line is drawn across the drum. The poise is set at



successive increasing loads till the desired maximum is reached; then, after increasing the pressure beyond this maximum, the same loads are traversed in the opposite direction. The cards are similar to that shown in Fig. 3. All the lines are drawn between the two vertical lines, those taken with rising pressure being extended to the left, those with falling pressures to the right. It will always be found that of the two lines drawn at any one pressure, the one taken with decreasing pressures is above the other. This is due to friction and lost motion which tend to make the pencil lag behind its proper position. In working up a card the arithmetical mean of the two readings is taken at the true reading. The method of obtaining the "constant of reduction" for any spring is illustrated by Fig. 4, which gives the calibration of a spring tested both hot and cold.

The heights of the lines on the card above the mean

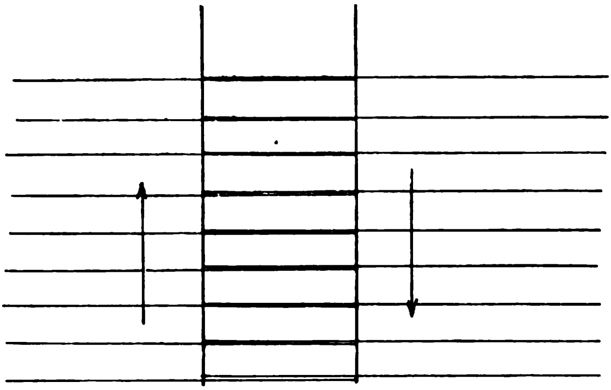


FIG. 3.

atmospheric line are measured in terms of the nominal scale of the spring. The differences of these readings (correcting for friction and lost motion as explained above) from the actual pressures as given by the weighing scale, *i. e.*, the "errors of the mean readings," are plotted as ordinates against actual pressures as abscissae. The curve through these points is a straight line if the elasticity of the spring is perfect. The value of the constant of reduction depends entirely upon the *inclination* of this line and is not affected by its absolute position. The line should pass

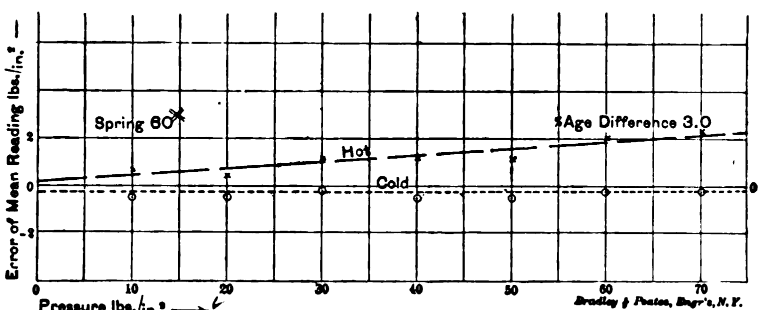


FIG. 4.

through the zero of ordinates, and if it does not it is evident that friction or lost motion have shifted the atmospheric line on the indicator card from its true position. As all the pressure lines on the card are measured from the atmospheric line, their readings will be in error by the same amount, which will have the effect of

shifting the curve of errors shown in Fig. 4 parallel to itself. The tangent of the inclination of this curve to the horizontal is, if the scales of ordinates and abscissae be equal, the percentage of error of the reading of the spring. Where, as in Fig. 4, the scales are different the tangent must be divided by the ratio of the scale of ordinates to that of abscissae.

If the calibration line is horizontal the spring is correct; if it inclines upwards from the zero of ordinates the spring is weaker than nominal strength and the percentage error must be subtracted from unity to give the reduction factor of the spring; if it incline downward it is stronger and must be added.

BOOK NOTICES.

TRANSACTIONS OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. Vol. xiv; 1893.

This is the volume containing the papers presented at the New York meeting of December, 1892, and at the Chicago meeting of 1893; the collection constituting the work of the great Congress of the International Exposition, of which the Society was the responsible director. It includes an enormous amount of the most valuable matter ever brought before a learned society or engineering convention. The volume before us is a book of over 1400 pages, rich in all that interests the professional, and in fruits of new and original investigation, which must prove of great value to the world. Many of the ablest engineers of Europe, as well as of America, contribute to this cyclopedia of technical literature and information. We find also numerous papers from the great technical schools of this country and foreign lands, and among these an exceptional number from our own faculty and graduates. The discussions, hardly less valuable and instructive than the original papers, contain a vast amount of miscellaneous information from all classes of workers, writers, and investigators. Among the most notable papers are those of Durand on Screw Propellor Efficiency; Rites on the Shaft Governor; Bissell on Lathe Bed Deformation; Richmond on the Refrigeration Process; Carpenter on Economy of Engines with varying loads; Dwelshauvers-Dery on the Theory of the Steam-Engine; Huet on Drainage of the Netherlands; Mallett on Locomotives; Goss on Locomotive Tests at Perdue; Thurston on Technical Education in the United States; Von Borries on Compound Locomotive

Development; Herrman on Centrifugal Machines; Durfee on Interchangeable Construction; and reports on tests of Materials and on Locomotive Standard Tests. Even the notices of deceased members are exceptionally well and discriminatingly prepared. The volume is a notable one, even among the many notable publications of this now large and important society.

The usual list of members is omitted, in the press of contributed matter; but, if printed, it would show a total of nearly 1650, the growth from an insignificant number in a short life of but a dozen years. Sibley College graduates, it should be remembered are eligible to junior membership in this society, and many have already taken advantage of what is unquestionably a valuable privilege. The volume is handsomely printed on excellent paper and from a font of beautiful type. It is a credit to its contributors, to its editor, the accomplished secretary of the society, to the printers, and to the binders. Every young engineer should at least examine it carefully and read some of the more original papers. The set is complete and can be found in the library whenever it is desired to consult it.

—Dr. Thurston, as chairman of the Treasury Commission on Safe and Vault Construction, sent a report of the work of the committee to the secretary of the Treasury, who in turn submitted it to the Senate. The report has been printed in pamphlet form. It contains as a part of the report of the Commission, a description of the vaults and safes of the Treasury as compared with those of modern banks and safe deposits. The result arrived at is that the government is much behind modern practice; that the chief safeguard in the treasury is the efficient corps of watchmen employed there. The different kinds of safes are described and their relative values shown. Also, the methods employed by the modern safe-breaker in entering money repositories are exhibited at length. The appendix to the document is taken up with reports of an extensive series of experiments conducted by Professor C. E. Munroe and Lieutenant Rodman, to determine the effect of high explosives on the laminated and the Corliss systems of safe and vault construction. It is very richly illustrated with reproductions of photographs taken during the experiments.

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COLLEGE ETHICS.

In an editorial, some months since, under the above title, we asserted that, at Cornell, the proportion of men who preferred the quiet manners of the gentleman to the boisterous ways of the boor and the "rowdy," and who believe that a gentleman cannot, as the honest man will not, commit even the petty crimes, such as sneak-thieving, cheating at examinations, or "hazing," after the manner of the bully of the days of "fagging" in the old English schools, is exceptionally large, even in comparison with the numbers of well-bred, courteous gentlemen in the best of the older colleges. We wish now to re-assert the fact, for the comfort of alumni and friends of Cornell, who have possibly feared that recent events may have given some grounds for doubting it.

In every college, and even in universities engaged in the promulgation of the higher learning and advanced professional work, there is always a number of men, seldom large in the aggregate, and always relatively a small proportion of the whole body of students, who are either ill-bred and know no better, or who have the instincts of the bully and the rowdy, and who, occasionally, break through the bonds which ordinarily hold them within the limits of the law. The University has just suffered a great misfortune through the criminal folly of two or three such ; but the great mass of students, in all classes and courses, neither knew nor suspected the possibility of such an occurrance ; nor would one man in a hundred have approved the proposed infraction of the laws of good manners and decency, any more than they would now fail to condemn and disown complicity in the resulting crime. The Cornell student is an exceptionally quiet and orderly citizen, earnest, hard-working, and wholesomely ambitious. Even the college "athlete," against whom so much is declaimed by ignorant and ill disposed critics of college men, is seldom boisterous, and, at Cornell, certainly, is held more strictly than other students, to regular habits, correct living, and law-abiding principles.

The unquestionable, but undeserved, loss which has come to the University, of reputation for good order and good manners, and of pecuniary support in large measure, which otherwise was thought assured in various ways, comes of acts of folly rather than of knavery, and is a misfortune, not a fault, of the college. An old saying of the earlier generation, "in every class may be found a thief," may be supplemented by another : in every large institution of learning are a very few, generally found at the tail-end of their classes, who lack either good sense, good breeding, or good principles, and from whose follies the great body of good men and the University may now and then suffer. This misfortune has come to Cornell ; but the fact is only the strongest of reasons for still more hearty support on the part of every alumnus and friend of an institution, than which no other in the whole land is more deserving. Our friends may rest absolutely assured of the excellent moral tone and most commendable spirit which dominates our whole student body.

The Faculty have done their full duty in this as in every other case. They have repeatedly informed the civil authorities that, while the latter are responsible for the preservation of the peace and the detection and punishment of offenders against the civil law, the university authorities will aid them in all ways in their

power. The college has no police or judiciary powers and must necessarily, for this if for no other reason, leave such matters mainly to the city police and courts. Students detected in crime and identified by the civil authorities are promptly sent away and, in cases of minor breaches of good order are dealt with justly. The sentiment in regard to such matters at Cornell has always been admirable, and that sentiment is to-day more pronounced than ever before in favor of good manners, good morals, and good work.

SIBLEY TOURS.

The annual inspection tours of Sibley students were originated by the present Director of Sibley College in the year 1886, for the purpose of giving to the students the advantages of practical observation among factories and power plants, at as low a cost as possible. Undoubtedly they are also advantageous in bringing Cornell University and Sibley College to the attention of manufacturers and others.

When first established, the SIBLEY JOURNAL, then known as the CRANK, devoted considerable space to a detailed report of the trips. In the April issue of '87, seventeen pages were occupied with the accounts of the excursion of that year, which included Philadelphia, Wilmington, Bethlehem and Chester. The next year only five pages were devoted to this purpose, and this amount dwindled down to two pages, to one page, and finally to only notices. This year a credit of one "hour" is allowed by the department for a satisfactory report.

NUMEROUS answers have been received to the circular letter asking for contributions, subscriptions and personal notices, that the SIBLEY JOURNAL sent out with its last issue. The answering letters were full of interest and contained several suggestions that, if, on further investigation are found to be practicable, will be complied with. One of these is to the effect that a supplement to each issue be published, containing abstracts of theses, the supplement to be sold by special subscription. In this connection it would be well to say that for several years past the June number has contained thesis abstracts, but that the number and character of such has necessarily been limited by the expense involved. If a sufficient support could be guaranteed the present Board would undertake to publish a special issue at about the end of the year that

would contain nothing but thesis abstracts and the results of thesis investigations. A number of writers have expressed themselves desirous of learning "more about the College and its work." The Board has endeavored to include in the regular issues some of the results of investigations carried on at the College, and will continue to do so. In regard to the College news, *i. e.*, the events transpiring at the University, of general interest to graduates, we desire to say that in the three remaining issues of this year, a certain amount of space will be devoted to reports of the important events in University circles during the past year. Any further suggestions from friends will be gratefully received.

REWARDS FOR MERITORIOUS DISCOVERIES AND INVENTIONS.

The Franklin Institute has recently sent out a circular containing the following note in regard to the rewards which are distributed under its direction :

"The attention of ingenious men and women is hereby directed to the fact that the Franklin Institute of the State of Pennsylvania for the promotion of the Mechanic Arts may grant, or recommend the grant of, certain medals for meritorious discoveries and inventions which contribute to the promotion of the arts and manufactures.

"The character and conditions of these awards are briefly stated in the following :

"The Elliott Cresson Medal, founded in 1848 by the gift of the late Elliott Cresson. This medal is of gold, and by the terms of the deed of trust may be granted for some discovery in the arts and sciences, or for the invention or improvement of some useful machine, or for some new process, or combination of materials in manufactures, or for ingenuity, skill or perfection in workmanship.

"The John Scott Legacy Premium and Medal (Twenty dollars and a medal of bronze), awarded by the City of Philadelphia. This medal was founded in 1816 by John Scott, a merchant of Edinburgh, Scotland, who bequeathed to the City of Philadelphia a considerable sum of money, the interest of which should be devoted to rewarding ingenious men and women who make useful inventions. The premium is not to exceed twenty dollars, and the medal is to be of copper, and inscribed 'To the most deserving.'

"The control of the Scott Legacy Premium and Medal (by Act of the Ordinance of Councils in 1869) passed to the Board of Directors of City Trusts, and has been referred by the Board to its Committee on Minor Trusts, and that Committee has resolved that it will receive favorably the name of any person whom the Franklin Institute may from time to time report to the Committee on Minor Trusts as worthy to receive the Scott Legacy Premium and Medal.

"The Edward Longstreth Medal of Merit, founded in 1889, by Edward Longstreth, Machinist, and late member of the Baldwin Locomotive Works. This medal is of silver, and may be awarded for useful invention, important discovery, and meritorious work in, or contributions to, science or the industrial arts.

" Full directions as to the manner and form in which applications for the investigation of inventions and discoveries should properly be made will be sent to interested parties on application to

WILLIAM H. WAHL, Secretary Franklin Institute,
Philadelphia, Pa., U. S. A."

CRANK SHAFTS.

—An interesting incident, showing the remarkable control which marine engineers exercise over their engines, is the recent performance of the twin-screw steam ship Paris, in which she was navigated for a distance of 500 miles with no other steering appliance than that furnished by the varying speed of the engines turning her propellers. An ocean vessel must be very carefully managed under the best conditions of efficient steering gear; but when the rudder has been totally disabled and the ship still steered successfully, we must acknowledge it to be a wonderful exhibition of skill.

—Owing to the fact that Crank Shafts were crowded out of our last issue we have not had the opportunity to express our sympathy with Perdue University at Lafayette, Ind., for the loss that she sustained in the distruction by fire of the new Engineering Laboratory. It was one of the best-equipped in the country, and was commencing its work in a most satifactory manner. Professors Goss and Flather had designed the building and planned its equipment on an unusually large scale, and had secured the very complete realization of their plans. The building had been opened for work only a few weeks before, but had already been shown to be one of the best-arranged, "plants" of

the kind yet constructed. A large amount of interesting work was planned, and some was already in progress.

—The editorial department of *Locomotive Engineering* for February, 1894, contains a sensible article from which we extract a paragraph : "The writer passed seven years on the footplates of British locomotives, and about the same time in the cabs of American locomotives. The teaching of this experience is, that a comfortably housed engineer can attend much more closely to his duties than one standing exposed to the weather. The British engine driver is too often engaged trying to escape discomforts which distract his mind from the working of the engine. An engineer who is overcome—prostrated with fatigue—is a dangerous man to be in charge of an engine. In that condition it is physically impossible for him to devote close attention to the numerous duties devolving upon him. A man standing gets worn out much more quickly than one sitting, which is good and sufficient reason why good, comfortable seats should be provided."

—The problem of lighting railroad cars is one which has long remained an interesting, though unsolved, one to all railroading men. Many systems have been tried and found unsatifactory for one reason or other, among them gas, oil, and several forms of electric lighting. It is said, however, that there is now one of the latter class that has been tried and found to work very satisfactorily. A dynamo is placed in the baggage car and is run by a belt from the axle. Current is supplied to a battery of storage cells, which in turn furnishes the current to light the incandescent lamps placed in the cars. The dynamo is so designed as to be automatically regulating to a very high degree, and automatic cut-out devices are provided whereby the generator is cut out as soon as the speed of the train falls below a certan amount. In this way a continuous current may be supplied to the lamps and still no extra demand made on the locomotive at times when it is in need of all of its power for traction purposes, as on grades. The inventor of the system is Lieut. Isaac N. Lewis, U. S. A., and the apparatus is manufactured by the Lewis Electric Co., of New York.

—In this age of improvement and economy, experimenters are seeking vigorously for new methods of turning existing power into useful channels. Besides those sources commonly availed of in practice, such as coal, waterfalls and air-currents, new schemes are being tried. Generally these are interesting only for their novelty. One instance, however, of what appears to be a successful application of a rather unusual source of power, is

seen in the wave-motors in use at several places on the Jersey coast. One of these machines, used to pump water, utilized wave-energy by means of a large paddle hinged at the top and reaching down into the water. The motion of the paddle, due to the rolling in of the waves, is communicated to the mechanism of the pump. Another device, used to furnish water for a summer hotel, operates a pump by means of the rise and fall of a float on the surface of the water. The objection often justly raised against attempting to utilize wind-power, water-power and the like—the high cost of installing and operating the expensive machinery needed—does not seem to hold in this case, for the mechanism is inexpensive and requires very little care.

Mr. J. E. Watkins, Curator of the Engineering Section of the U. S. National Museum, at Washington, in an address before the National Electric Light Association, at Providence, gave the following impressive view of the progress of the electrical industries during recent years:

"The electrical industries are called into service in every branch of human labor. If we visit the farm we see the electric motor applied to the threshing machine; while telpherage is found to be an economical means of collecting and transporting grain and farm produce from the field to the store house and railway station. One progressive farmer, controlling thousands of acres, sits at his desk and gives directions by telephone to overseers stationed at different points on his immense farm.

"Who can tell what influence the discovery of Sir William Siemens that diffused light from arc lamps of 2,000 candle power, placed one to each one thousand square feet of surface is sufficient to replace the sun in its beneficial action upon plant life may have in the future upon floriculture and horticulture in the land of short days and long, dismal nights?

"If we enter the mine, we find the tunnels and gangways lighted by the electric light—the electric drill is at work in the heading, the electric fan produces ventilation and the electric locomotive collects the coal or ore from the miners in the chamber and delivers it without heat or smoke to the steam railway for transportation.

"If we sail upon the sea our ship is guided by the magnetic needle and steered by electric gear; we see the sub-marine torpedo boat propelled by electricity; in the light house burns the electric beacon; the electric search-light protects us from collision in the darkness and the fog; while electricity is put to a hundred other uses on shipboard.

"Upon the land we find in the United States alone enough electrical railroads in operation which, if placed in one continuous line, would reach from New York to Salt Lake City, and upon which nearly one million and a half passengers ride every day.

"We illuminate our public streets and parks, our railway stations and public halls, our offices and homes, by electric systems which ten years ago were undiscovered or in the experimental stages. By the movement of a single lever the area of a whole city is turned from darkness into the brightest day. Central electrical lighting stations in America exceed in number the central gas lighting plants by over 50 per cent.

"If we visit the printing office we find that the news is collected by electricity, the presses are driven by electricity, the papers are printed from forms containing electrotypes, an electric folder and paster completes journals, which are conveyed to the street for delivery by an electric elevator."

PERSONALS.

'84.

John Waring, the inventor of the Novah incandescent electric lamp which has so recently been in litigation with the Edison patents, upon graduation at Cornell, was employed by the Mather Electric Co., and put in charge of their laboratory where he superintended testing and did special work. Among his valuable services with this company were the perfection of resistance boxes for fine measurements, the design of a copper coil for direct reading of temperatures in resistance boxes, and work on delicate galvanometers and meters. In 1890, the Perkins Electric Lamp Company secured him as electrician. With this firm he remained till December 1, 1893, when its factory closed.

'92.

P. H. Knight is doing important work as erecting engineer with the Westinghouse Electrical Manufacturing Co. At present he is at Louisville, Ky., installing heavy machinery, including a set of E. P. Allis compound engines directly coupled to four 5000 K. W. 2000 volt A. C. dynamos with twelve foot armatures, and one 500 K. W. direct current dynamo.

H. C. Nelson, in the employ of C. O. Mailloux, consulting electrical engineer, New York City, has been engaged in winding the fields and armatures of motors used for training, elevating, and lowering dynamite guns made by the Pneumatic Torpedo Construction Co. He had charge of the operation of some of these motors when the dynamite gun bought by Brazil for the "Nictheroy" was tested before officials of that government at Coldspring, N. Y. Later, he has conducted several important tests and is now designing the wiring of city buildings and inspecting the work done from his designs

Carroll L. Hoyt, formerly of THE CRANK editorial staff, is in the engineering corps of the Dickson Manufacturing Co., at Scranton, Pa., where he is doing valuable work in the construction and erection of mining machinery. The hoisting engines are both horizontal and vertical, the latter being in triple and quadruple expansion types and ranging up to 2,500 H. P.

'93.

H. M. Marble, non-grad. '91, was, during the interval between April, 1891, and April, 1893, employed by his father, E. M. Marble, late Commissioner of Patents, in his extensive business as patent solicitor and lawyer. After graduation, he returned to his father's employ and has recently been admitted to the firm, now styled E. M. Marble & Sons. Their offices are in New York City and Washington, D. C.

J. S. Cothran, Jr., is Master Mechanic of the Chester and Lenoir Railroad. His headquarters are at Chester, South Carolina.

Frank C. Cosby was electrician on board the battleship "Illinois" at the World's Columbian Exposition. He superintended the lighting of the ship and operated the two 36-inch projector 1,000,000 candle-power search lights. Since the Fair, he has been in Washington, D. C., settling up the affairs of the naval exhibit.

J. F. Cook, in the employ of the Dickson Manufacturing Co., is associated with Hoyt, '92, in his work as constructing and erecting engineer of mining machinery,

John D. Mickle, non grad., is school commissioner of Columbia County, N. Y. He holds office by popular election and for three years. His headquarters are at Chatham, N. Y.

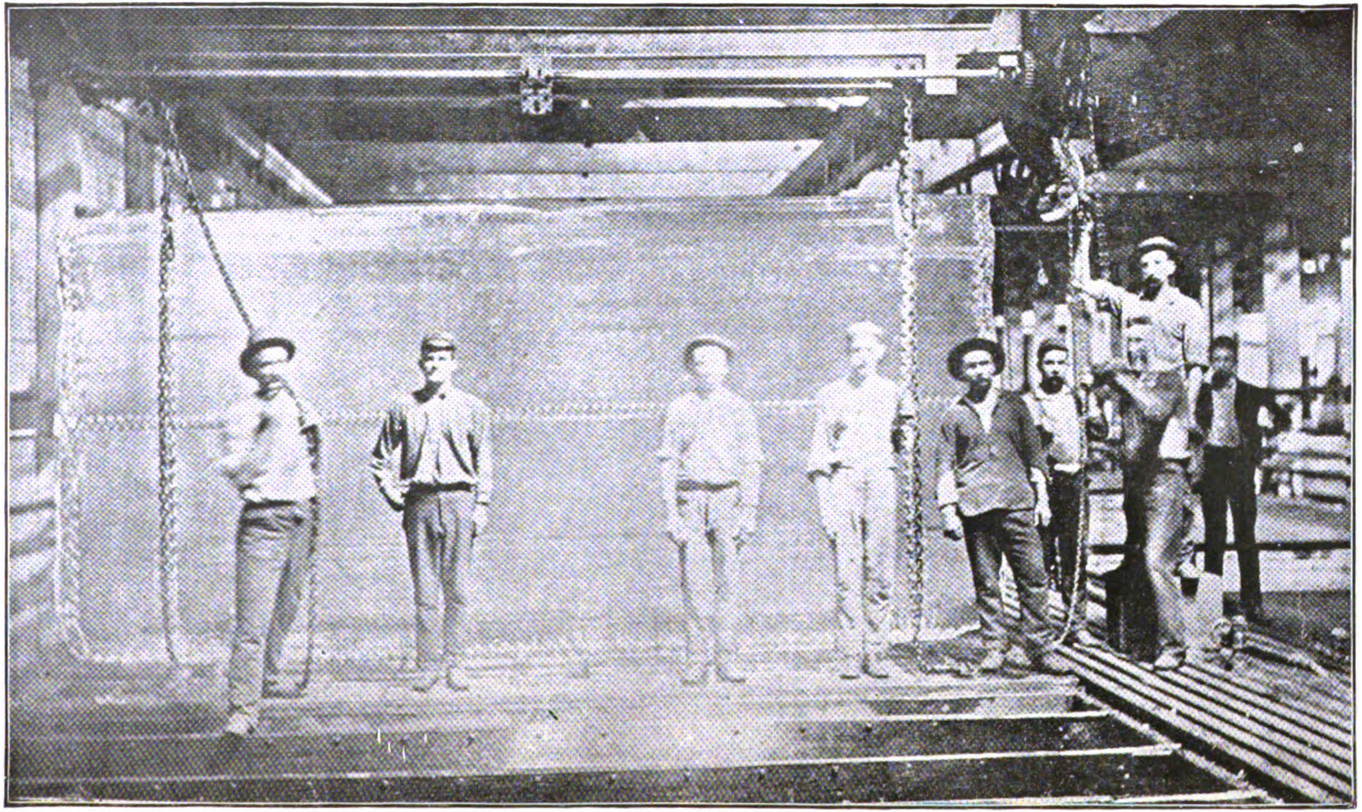

Plate of Ice, 16 feet x 8 feet x 12 inches, as Clear as a Plate of French Glass, Manufactured in Refrigerating Machine Built by Frick Company, Engineers.

THE SIBLEY
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IN CORNELL UNIVERSITY

"The leading object shall be, without excluding other scientific and classical studies, and including military tactics, to teach such branches of learning as are related to Agriculture and the Mechanic Arts, in such manner as the legislatures of the States may respectively prescribe, in order to promote the liberal and practical education of Industrial Classes in the several pursuits and professions in life."—[An act donating public lands to the several States and Territories which may provide Colleges for the benefit of Agriculture and the Mechanic Arts, July 6, 1862.]

SUBMARINE TELEGRAPHY.*

BY A. E. KENNELLY.

The first submarine telegraph cable was that laid across the British Channel in the year 1850. It consisted simply of a copper wire covered with gutta-percha, and proved far too slight to meet the severe shocks and strains to which it was exposed by the waves. It lasted only one day. In the following year further attempts in this direction resulted in successfully laying a much more substantial cable. This time it consisted of four wires, and was so well constructed and laid that the twenty or thirty miles then placed in position are still in operation. Soon after this, more ambitious attempts were made, this time deep water being chosen. A serious obstacle was encountered then, as now, in running out the cable from the ship, for it was found that the weight of the cable was so great as to cause it to run out very rapidly even when the ship was at a stand-still.

At this time prominent men directed their attention to the great problem of establishing telegraphic communication between the continents. Dr. Werner Siemens invented a device for retarding the motion of the cable when leaving the ship, that is essentially the same as the one in use to-day, and it is largely due to his skill

*Notes on a lecture delivered by Mr. Kennelly before Sibley College, on Feb. 9, 1894.

and enterprise, that the early attempts succeeded. The retarding device consisted simply of a large drum, to the periphery of which brakes could be applied, and around which the cable was wrapped.

To the present time there have been laid a total of about 300 submarine cables, representing a total mileage of about 140,000 knots—a knot being about one sixtieth of a degree of latitude, or about 2029 yards. Of this number, eleven cables cross the Atlantic. The time during which this development has been made is only 40 years.

In constructing the cable, seven copper wires are twisted together, six being stranded about a central one, and the strand passed through a tank of melted gutta-percha. The latter is found, after forty years experience, to be an insulating material admirably adapted to this use. When immersed in sea water it does not disintegrate, nor does any deleterious chemical action result.

In order to prevent small leaks in the covering, three distinct layers of the gutta-percha are put on and each layer thoroughly cemented to the one just under it. Before the practice of cementing the layers together was begun it was found that water could leak through a hole in one covering and creep between the layers to a hole in another covering, and so on to the cable. This cement, known as Chatterton's Compound, is composed of one part of resin, one of tar, and three of gutta-percha. The process as so far described completes the core of the cable. Upon this are wound in opposite directions two coatings of hemp, and after this, it is wound with iron wires, which in their turn receive two final coatings of tarred tape.

An ocean cable is not of the same diameter from end to end, but is divided into what are known as the deep sea portion, the intermediate sections, and the shore ends. The latter sections are subjected to much severer wear than the former, due to the chafing caused by the motion of the shallow water. Consequently, the deep sea part is made smaller in cross section than the shore end, being about one inch in diameter and weighing less than two tons to the knot. The cable is made in lengths of a half mile, and to make the completed cable these sections must be joined together. The process of making a joint is a delicate one, and must be performed with great care. Each copper wire is soldered, and a binding wire of copper soldered on to the joint, which is then very carefully insulated. The workman, whose sole business is

making joints, must have his hands perfectly clean and dry and entirely free from any kind of grease. The splicing of the ends is done with great caution. Before being used the half mile lengths are coiled in tanks under water, by which means they may be kept for an indefinite period. When ready to lay, the sections are joined together as above described, and coiled in the tanks of the ship, where the cable is again submerged in water. In placing in the tanks, which may be 20 ft. deep and 40 ft. in diameter, the cable is coiled from the outside of the tank in towards the center; then it is brought out and the second layer coiled in the same way. Since the weight of these tanks filled with the cable is very great, good marine engineering design is required to build tank frames that can safely stand the strain.

At every point of the manufacture, where it is feasible, tests are made to insure the soundness of the insulation. When the coiling is completed water is run into the tank, the first result of which process is to raise the temperature of the cable about 5 degrees Fahr., due to chemical action.

Everything is now ready to begin laying the cable, but haste is not imperative for it may be preserved indefinitely when submerged in the tanks. The shore end is laid first. To do this it is often placed on a barge; the barge is towed to the point at which operations are to be begun and run as close as possible to the shore; one end of the cable is dragged to the shore; and the remainder is paid out as the barge is towed away. The sea end of the cable is sunk on a mushroom anchor secured to a buoy. When the ship containing the sea portion is ready to begin operations the buoyed end of the shore part is taken up and very carefully spliced to the ship's cable, after which the whole is tested, and the splice dropped over the bow. The ship is then ready to proceed on its way. The path of the cable in passing from the ship's tank to the bottom of the sea lies first under jockey wheels, to take up the slack, then over a drum around which three turns are made, under a dynamometer, to determine the amount of tension, and thence over the stern to its final resting place. The dynamometer is an important accessory, for it is essential to know just how much strain is being exerted on the cable. This device consists simply of a sheave free to move in vertical slides, and resting on the moving cable, thus supporting a platform on which are placed weights. To the platform there is connected a plunger working in an oil cylinder on the principle of a dashpot, the effect being to restrain any tendency on the part of the

platform to respond too suddenly to a sudden slackening of the cable, and thus cause a sudden fall or concussion. A considerable difference of opinion has long existed, and still exists, upon the theory of the tension to which the departing cable should be subjected. There are two rival theories in regard to the matter, (1) that the frictional force on the cable moving through water parallel to its axis varies as the velocity, and (2) that it varies as the square of the velocity. Probably both are partly correct, but the question is still unsettled, for there are a number of qualifying conditions, such as the method of determining constants, the state of the weather, etc. The strain is usually adjusted by estimation based upon experiences, until the nautical observations of the ship's position compared with the paying out records indicate whether the slack is in excess or defect.

A constant watch must be maintained and great precaution exercised, lest, in leaving the tank, the cable should become fouled at some point. Especial care must be taken when the cable is changing flake, *i. e.*, when a coil or layer is completed and another starts. Men are stationed at different points to watch constantly the strain, the log, and in fact everything connected with the cable.

In the testing-room, also, a constant watch is being kept. Tests are made continuously to see that the insulation is intact. If at any time a defect should occur the first thing to do is to locate it, electrically and geographically. The defect may be of two kinds, a rupture of the insulation—a "fault,"—or a complete parting of the cable,—a "break." If the cable falls below its guaranteed electrical condition within a month from the laying, the makers of the cable are usually under contract to repair the same, but if a month has elapsed, they are released entirely from all responsibility.

When the spot on the chart at which the leak or rupture has occurred is known, a ship proceeds to the spot and takes a sounding. A mushroom anchor, which is one having its fluke continuous all the way round and not divided into prongs, is lowered away. This will moor the cable but will not get entangled in rocks. A grapnel about 5 ft. long is then put down. The grapnel is attached to a chain, and the upper end of the chain to a section of rope 300 fathoms long, which in turn is connected by means of a swivel to another piece of the same length, and so on. The grapple rope is run out over the bow, first passing under a dynamometer which shows by the strain when the cable is

hooked. A slow and steady rise of the dynamometer shows cable ; a sudden rise usually indicates rocks. One difficulty encountered is the frequent breaking of the grapnel prongs on rough ocean beds. Sometimes a centipede grapnel is used, which will allow a prong to be easily replaced by a blacksmith on board ship, and sometimes Jamieson's patent grapnel is used, which allows the prongs to bend under if a rock is caught. The grappling for an injured cable and the work attendant upon bringing it to the surface is about the most interesting and exciting part of the experience of men engaged in submarine cable work. After being brought up to the bows the cable is chained and cut preparatory to making the required repairs.

The message carrying capacity of a cable is determined by what is known as the K R law, which briefly, is as follows : Let K = total electrostatic capacity, and R = total ohmic resistance. Then the carrying capacity varies inversely as K R.

The carrying capacity of the Atlantic cables is about twenty-five words per minute, or if the duplex system is used, fifty in all are attained. The speed of transmission is obviously inversely proportional to the square of the length. The expense of laying and attending a cable is very great, the original cost after manufacture alone being about $1,000 per mile.

Considerable experience is necessary in the handling of submarine telegraphs. It takes six months to make a fairly good cable operator from a good telegraph operator. The receiving is done by means of a siphon recorder and a mirror galvanometer, only very small currents being used. The first Atlantic cable was ruined by excessive currents ; only one cell of battery can be used if necessary, although the working battery of an Atlantic cable is usually about 30 cells. The translation from one cable to another must all be by hand. No automatic relays or repeators can be used, but operators are so skillful that a human relay practically is almost as efficient as a merely mechanical instrument would be.

MECHANICAL REFRIGERATION—ARTICLE III.

BY R. C CARPENTER.

THE EFFICIENCY OF THE REFRIGERATING MACHINE.

It was shown in the February number of THE SIBLEY JOURNAL that, supposing no losses in the machine, the heat received from the refrigerator K_1, increased by the heat equivalent of the mechanical work, $A\,(W_c - W_e)$, equals the heat discharged, K.

$$\text{That is, } A\,(W_c - W_e) = K - K_1. \qquad (6)$$

As $W_c - W_e$ is an expression for the net work done during the entire revolution in compressing the gas, we can substitute for this a single quantity, and thus make the form of equation (6) somewhat more simple. Thus, substitute Aw for $A\,(W_c - W_e)$ in equation (6), then we shall have,

$$Aw = K - K_1. \qquad (8)$$

If w is expressed in foot pounds, $A = \frac{1}{778}$; if w is expressed in horse power, $A = 42.42$.

If the refrigerating machine were not perfect, the mechanical work expended, Aw, would be less than the increase in the heat transferred, and we should have for the imperfect machine,

$$Aw < K - K_1.$$

The amount of refrigeration, or cold, produced is the quantity K_1, since that is the heat taken from the colder body and transferred to the hotter. This is, in fact, the object of the refrigerating process, so that this quantity may be considered the useful work. The total energy supplied is the mechanical work of compression. If we take as the measure of the efficiency of the machine the ratio of the useful work to the total energy expended, we will have the equation already given for the efficiency (see eq. 7, page 221), viz.:

$$E_1 = \frac{K_1}{A\,(W_c - W_e)} = \frac{K_1}{Aw}. \qquad (7)$$

The above expression is for the actual efficiency for the work done. Since, in a perfect heat engine, we have $Aw = K - K_1$ (8), by substituting we should have

$$E_2 = \frac{K_1}{K - K_1}, \qquad (9)$$

which would be the efficiency for a perfect heat engine, and this would be equivalent in the case of a reversible cycle to

$$E = \frac{T_1}{T - T_1}, \tag{10}$$

which is the reciprocal of the expression for the efficiency of a heat engine working in the Carnot cycle.

As it is well known that the thermodynamic efficiency of an engine working in a Carnot cycle is less than one, its reciprocal must in every case be correspondingly greater than one, and must reach its limit as noted by discussion of equation (10), when $T - T_1$ has the least value, or when this value approaches 0, in which case the limiting value of the efficiency approaches infinity.

This expression for the efficiency of a refrigerating machine is adopted by every writer on the subject, so far as known to the author, and if we consider the refrigerating machine as the inverse of a heat engine, the view is certainly correct and needs no explanation. The expression asserts what is certainly true, that for a given expenditure of work, the output or energy realized is much greater than that put in, or from such a standpoint, the machine has a greater efficiency than unity.

This is capable of explanation as follows: Thus in the heat engine working between the limits of temperature, T and T_1, the greatest possible work to be realized, is proportional to $T - T_1$. That is,

$$e = \frac{T - T_1}{T}.$$

If we denote the corresponding amount of heat by H and H_1, we also have,

$$e = \frac{H - H_1}{H} = \frac{Aw}{H}. \tag{11}$$

For a Carnot engine, $\dfrac{H - H_1}{H} = \dfrac{T - T_1}{T}.$

From equation (11), $Aw = H - H_1$, which is similar in every respect to equation (6) or (8) for the refrigerating machine.

By transposing this we have,

$$H_1 + Aw = H, \tag{12}$$

that is, the heat equivalent of the work added to that discharged at the exhaust, is equal to that received.

Now, in the heat engine the amount discharged by the exhaust is very great. In the case of a refrigerating machine, we suppose that heat is received at the lower temperature, in other words,

flows in at the exhaust pipe, is increased by the mechanical equivalent of the work done, and that the total is discharged at a higher temperature.

There is no reason why H_1 should not be many times greater than Aw; in fact, they stand in no closer relation in a theoretical way than the heat discharged in the exhaust does to that transformed into work in the steam engine.

In the thermal efficiency of the perfect refrigerating machine, we have the limit of maximum efficiency as infinity, and we can reasonably expect that the actual efficiency will in every case exceed one, as computed in equation (7).

HEAT LOSSES.

In the case of the steam engine, heat is taken from the steam to warm up the cylinder and to keep it warm, giving rise to the loss known as cylinder condensation ; in addition, heat is radiated into the surrounding space. These losses reduce the working value of the steam 20 to 50 per cent.

In the refrigerating machine these losses are all negative, and tend to increase the difference between that received and that discharged.

The effect of the heat losses would be as follows : In the compression, the cylinder becomes heated, and this heat is only partially discharged to the condenser, the remainder keeps the cylinder warmer than it otherwise would have been even at the end of expansion. This heat in the cylinder walls passes out to the entering gas as it flows in, and has the effect of raising the temperature, being thus exactly opposed in character, but otherwise similar to the loss of heat which occurs with a heat engine. During a great part of the revolution the temperature in the cylinder is below that of the room, in which case heat will flow from the surrounding room into the working cylinder.

This heat loss tends to increase the heat discharged and to lessen that received, so that it has a great effect on the difference of heat received and discharged.

If we consider equation (8), which represents in a general way the relation between the mechanical work and the heat transfer, for a refrigerating machine in which there are no heat losses,

We have, $Aw = K - K_1$.

The heat losses tends to diminish the supply of heat drawn from the colder body, hence K_1 is lessened for a given value of Aw or K, and we have as a result,

$$Aw < K - K_1.$$

The heat drawn from the colder body, K_1, can be called with propriety the *cold produced.*

The following table gives the result of a series of tests on Ammonia Compression Machines, made by C. Linde of Munich, and are of interest as showing the amount and character of the various quantities described. The table is copied largely from a paper read before the American Society of Mechanical Engineers, at the Chicago meeting, 1893. The units were reduced to one minute of time instead of one hour. It is noted that in every case Aw is less than $K - K_1$, and it should also be farther noted that the smaller this difference the greater the economical performance of the machine.

No. of Test.	1	2	3	4	5
Tempt. of brine—Inlet. Deg. Fah.	43.2	28.3	13.9	—0.3	28.3
—Outlet. " t	37.0	22.9	8.7	—5.9	23.1
Specific heat of brine per unit of volume	0.861	0.851	0.843	0.837	0.851
Quantity of brine per hour, cu. ft.	1039.4	908.8	615.4	915.0	800.9
Cold produced B.T.U. per min. K_1	5715.1	4399.1	2781.3	2024.5	3671.4
Temp. of cooling water—Inlet. Deg. Fah.	48.8	49.5	49.1	49.1	49.2
Temp. of cooling water—Outlet. Deg. Fah. . . . . t_c	66.7	68.0	67.1	67.3	93.4
Quan. of cooling water per hour. cu. ft.	338.7	260.8	187.4	140.0	97.8
Heat removed by condenser per minute, B. T. U. . . . . K	6305.9	5023.4	3509.5	2648.7	4518.9
Increase in heat . . . . . $K-K_1$	590.8	724.3	728.2	624.2	847.5
I. H. P. in compressor-cylinder w	13.82	14.29	13.84	11.98	19.75
Heat equivalent of work . . Aw	586.2	606.2	587.	508.2	837.1
I. H. P. in steam engine cylinder	15.80	16.47	15.45	14.24	21.61
Consumption of steam per hr., lbs.	311.5	336.0	306.8	278.8	430.1
" " " min., lbs.	5.19	5.6	5.11	4.65	7.17
Cold produced in B.T.U. per min. per I.H.P. in comp. cyl.	413.5	307.7	200.9	169.0	185.9
Cold produced in B.T.U. per min. per I.H.P. in steam cyl.	361.7	267.1	180.7	142.2	169.7
Cold produced in B.T.U. per min. per pound of steam	1100	785.6	543.9	435.8	512.1
Thermodynamic efficiency $(460 + t) \div (t_c - t)$ . . . . E_1	17.2	10.65	8.04	6.2	6.86
Actual efficiency, $K_1 \div Aw$ . . E_2	9.75	7.26	4.73	4.03	4.38
Ratio of actual to thermodynamic efficiency	.56	.68	.59	.667	.637
$Aw - (K - K_1)$	—4.6	—118.1	—141.2	—116.0	—10.4
*Lbs. of ice melted per lb. of steam	7.52	5.66	3.85	3.1	3.64
" " " " coal .	75.2	56.6	38.5	31.	36.4

* Latent heat of ice taken as 141 B. T. U.

Erratum to Article II.—Through an error in printing the cut of the single acting compression pump, given in our last issue, was inverted.

EXPERIMENTS ON THE TRANSMISSION OF HEAT.*

BY M. H. GERRY, JR., AND E. T. ADAMS,

Heat transmission is a subject of great importance to the engineer. Its applications cover the entire field of steam power engineering, of heating, of refrigeration, and in one way or another it enters into almost all branches of mechanical engineering. Wherever there is a furnace, a heat-engine, a dynamo, or a shaft turning in a journal, there are problems involving the transmission of heat.

As it is well known, heat may be transmitted in any of three ways; by radiation, by convection, and by conduction. The experiments about to be described relate to the last two. Very little exact information of value to engineers can be found in the literature of the subject. The conduction of heat by various single substances has been investigated by a number of writers, but the results are expressed almost universally in an arbitrary, comparative standard, and quantitative results are not given. Still more unsatisfactory is the information to be had relating to the transmission of heat from and through several different media. It is in this latter form, too, that the engineering problem nearly always presents itself; that is, in the form of transmission from one substance to another, and from that to still others.

Joseph Fourier has investigated this subject mathematically, but his elaborate analytical methods cannot be applied to practical cases because his assumptions cannot be fulfilled, and many of his quantities are physically indeterminate. Tredgold experimented on the transmission of heat from water through an iron vessel to air. Isherwood and others have published experimental results of transmissions, from steam, through vessels of various shapes and materials, to water. In most of these experiments, however, the range of temperature worked through is small, and in nearly every case the rate of heat transfer has been assumed constant. The most complete and valuable experiments on the subject are found in the work of E. Peclet, "Traite de LaChaleur."

The series of experiments made by the writers of this paper may be divided into three classes, and these subdivided again as given in the following table:

*Work done in connection with the course in Consulting Engineering.

Transmission from *Steam* .	through boiler plate	To *Water*.
	" cast iron plate	
	" boiler plate and scale .	
	" cast iron plate and scale	
Transmission from *Oil* . .	" cast iron plate	
	" cast iron plate and scale	
Transmission from *Air* . .	" cast iron plate	
	" cast iron plate and scale	

The apparatus and method of making the tests may be described as follows :—A non-conducting rectangular vessel was provided, and the iron plates to be tested arranged to form the bottom. Underneath this iron bottom was introduced in the different experiments, respectively, steam at atmospheric pressure, lard oil, and heated air. Above the plate when tested alone, water was caused to flow evenly over the surface by means of baffle-plates. In the experiments with scale, water was conducted over its surface in a similar manner, the joints between the scale and box being made tight by means of a little plaster of paris. The temperature of the medium under the plate was taken by means of thermometers, and where oil was used it was stirred continually to maintain a constant temperature throughout the mass. The temperatures of the water supplied and discharged, were also carefully taken, and the weight of water passing through the apparatus measured for a certain length of time, usually either five or ten minutes. From the weight and temperatures of the water the total B. T. U. passing through the plate in the time of the run were calculated readily. Having the time and dimensions of the plate, the rate of heat transmission in B. T. U. per square foot, per minute, and per degree, was readily obtainable.

In every case the rate of transmission increased with the temperature. In all cases, except that of steam, the increase of rate, as near as can be observed from the experiments is directly proportional to the temperature, and follows the law of Newton as given by Peclet

$$v = qt$$

where $v =$ rate

$t =$ difference of temperature.

$q =$ a coefficient variable with the media, its surface conditions, etc.

In case of steam the rate increases faster than the difference of

temperature, and may be expressed very nearly in a form given by Peclet:

$$v = ma^{\theta}(a^{t} - 1)$$

where v = rate;

m = a constant depending on the nature of the surface of the body;

a = the number 10,077;

θ = the temperature of the medium under the plate;

t = the difference in temperature.

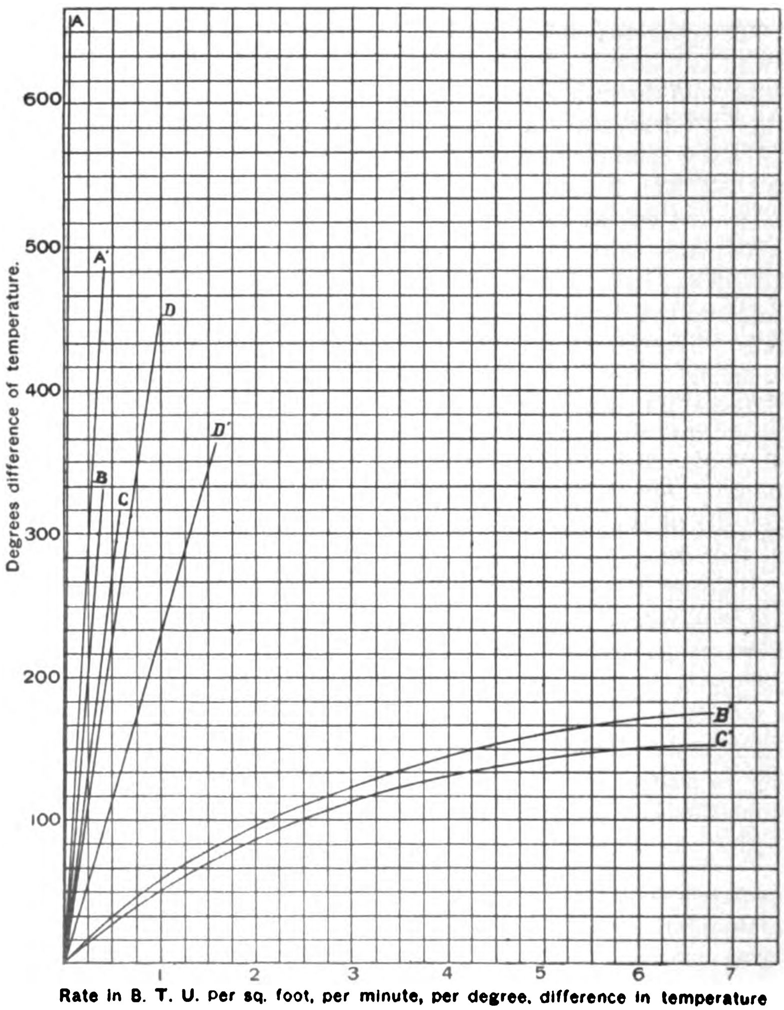

PLATE I—*Showing Transmission of Heat.*

A,	from air	through	cast iron and scale	to water.
A′,	" "	"	cast iron	"
B,	" steam	"	cast iron and scale	"
B′,	" "	"	cast iron	"
C,	" "	"	boiler plate and scale	to water.
C′,	" "	"	boiler plate	"
D,	" oil	"	cast iron and scale	"
D′,	" "	"	cast iron	"

The results of the experiments are given in graphical form, by the accompanying plate, all the curves being drawn to the same scale. The rate of transmission of heat, in B. T. U., is plotted against the difference in temperature, existing between the medium transmitting the heat and that by which it is finally received. All temperatures are given in Fahrenheit degrees. The medium receiving the heat was water, which was supplied at a constant temperature and discharged at some higher temperature, the mean of these two being taken as the true temperature.

Curve C′ shows the rate of transmission of heat from steam at atmospheric pressure, through a $\frac{5}{16}$ inch steel boiler-plate, to water. The surface of the plate was left as it came from the mill ; it was smooth and free from oil or grease.

C shows the rate for the same plate, under the same conditions, after a piece of carbonate scale 1⅛ inches thick was placed above the steel plate. The under surface of the scale was smooth and in close contact with the plate ; the upper surface was quite rough. The thickness was fairly uniform. In both cases the velocity of the steam below the plate was low, and its direction of flow was at right angles to that of the water above the plate.

B′ shows the rate of heat transmission from steam at atmospheric pressure, through a $\frac{7}{16}$ inch cast iron plate, to water. The plate was a good smooth casting, neither surface being finished, and both surfaces clean and free from oil or grease.

To get B the same piece of scale used with the boiler-plate was placed above the cast iron, the other conditions remaining exactly as for B′.

D′ and D. Here the medium transmitting heat was a bath of lard oil, the other conditions being as for B′ and B.

A′ and A. Again we have the same conditions except that we have a current of heated air transmitting heat to the cast iron plate. The velocity of this air current was somewhat less at the lower temperatures than it was at those higher ; but did not, in any case, exceed that common in the tubes of an ordinary steam boiler under natural draught. The direction of the air current

was parallel to the plate and at right angles to that of the water above the plate.

The very great importance of the condition of the surface of the medium through which heat is transmitted, cannot be too strongly emphasized. The equations of Newton and Peclet are indeterminate until the effect of the surface is known. This is well illustrated by two curves, not shown in the plate; the conditions were exactly the same as for B: from steam, through cast iron plate, to water, except that there was a thin film of oil on the bottom of the plate. The readings were somewhat irregular, but the average loss in transmissive power was fully fifty per cent., the heat transmitted being that much less than in case B, where the surface was clean.

The curves given represent the average result of several thousand observations, and we believe that they are fairly accurate. They show very clearly the comparative rate of heat transmission from steam, oil and air, under the conditions here given.

THE FACTOR OF SAFETY.

BY JOHN H. BARR.

"The capacity to decide upon the proper factor of safety is *the* important point in machine design."

This text probably contains much deeper truth than is commonly realized, even by those who are accustomed to employ that much abused weapon of defense, the factor of safety. Much has been written and said upon this topic and it would seem that the first duty of one who ventures to add anything is to justify his action.

The experience of the writer has led him to believe that many students and young engineers, (and possibly a few older ones), have a very inadequate idea of what is really included in the term, factor of safety, and if by these lines the conception is made a little more definite to some of the readers, their aim will be accomplished.

Most of the formulas of mechanics, as applied to design, are based upon theoretical treatment of the stresses induced by the action of given forces on the parts under consideration. There are many cases in which this course is perfectly logical, and the

conclusions are irresistible ; while in other instances members of a machine or structure are subjected to such a complicated system of stresses that analysis cannot be strictly applied, and less satisfactory approximations, or assumptions, in the present state of our knowledge, are unavoidable. This last condition of things introduces the first of many elements of uncertainty, and one of three methods of arriving at the proportions of the parts is possible. First, if the predominating action is capable of rational treatment, the part can be designed as if for the corresponding stresses, and such a margin as is dictated by experience or experiment is then allowed for the more uncertain elements. Second, analysis may be abandoned and resort may be had to empirical formulas derived from experiment. Third, the last, and not most uncommon, recourse is to guesswork, or as the designer would probably prefer to call it, judgment. This last method, when it is *real* judgment, based upon a large experience, has produced magnificent results ; in many cases, (especially for details and small parts), it is the only way to proceed. There is no intention in this sketch to belittle that invaluable faculty which has distinguished so many of the greatest designers that the world has ever known,—mechanical intuition. This, however, belongs to the *art* of engineering, and we are at present concerned with a more limited topic of the *science* of engineering. In the application of rational formulas, where such application is proper, we are dealing with the science, and in painstaking calculations, involving the employment of a factor of safety, this factor should be just as carefully considered as any other step in the process, or the work is neither art nor science. A man who cannot determine a rational factor of safety, can derive comparatively little benefit from a rational formula.

Text books frequently give an elaborate and tedious treatment for the design of a machine member, and then introduce an apparently very liberal factor of safety with very little ceremony. The student sometimes concludes that he might as well guess in the first place ; and this view is not altogether illogical, if the last step *is* a guess. It is a fact, as frequently stated, that dimensions found necessary in practice often demand a factor of 6, 8, 10, or even more, and facts are proverbially stubborn. In what follows an attempt will be made to account, in part at least, for this wide margin between what apparently ought to be, and what *is* necessary : and to show that the factor of safety is not, or at least need not be so largely a "factor of ignorance" as is sometimes sup-

posed. Let us first note what the so called factor of safety is and of what elements it is composed. Our formulas of mechanics are applied to a suitable material, and this introduces into the problem the properties of the substance. The most commonly used physical constants are the breaking or ultimate strength, and the modulus of elasticity ; the former is employed when the question is one of strength, and the latter in calculations involving rigidity, or stiffness. Confining our attention to the former, we are told to divide the ultimate strength by the factor of safety and to limit the working stress, under ordinary circumstances, to this quantity. This factor of safety is then the quotient obtained in dividing the ultimate stress by the allowable working stress, and the latter is usually derived from successful practice. In other words, the formula is made to give a practical result by the introduction of a factor which will secure practical proportions. If we are to ascend in a balloon and descend in a parachute, it will be wise to look well to the character of the parachute, for is it not the important part of the equipment? If we are to base our design on a factor of safety is it not worth while to give more than a passing thought to the character of this factor? Why is the large factor necessary? For an answer to the last question it will be of help to recall the actions which are brought to bear on the members of machines, and their effects.

The principal forces tending to produce stress in a working member of a machine are given by Unwin as follows :

(a). The useful load.

(b). Prejudicial resistances, as friction.

(c). Weight of the parts.

(d). Reactions of inertia due to changes in velocity.

(e). Centrifugal action due to change in direction of motion.

(f). Occasionally there are stresses due to constraint preventing expansion and contraction with changes of temperature, etc.

The ultimate stress is that at which rupture will occur ; the working stress is that which must be repeatedly sustained throughout the life of the machine. The latter is less than the former because machines are not made to be broken, and in all ordinary cases the parts must not even suffer appreciable permanent distortion. Furthermore, experiment has shown that a stress that may be applied once, or a few times, without rupture of the piece may break it if repeatedly applied ; and in most cases the load upon a machine is imposed an indefinite number of times. Again, we can never be sure that the piece that we actually use is as perfect as the piece we test ; and defects due to poor workmanship, mal-

treatment in construction, etc., may be unknown sources of weakness. Finally, there may arise contingencies which could not reasonably have been foreseen or calculated, but which may call out stress far in excess of the usual amount. In the choice of the factor of safety we should then consider the straining actions as indicated above, (and possibly others in special cases); and we must allow a working stress less than that corresponding to the ultimate strength, because:

(a). The elastic strength is less than the ultimate.

(b). Repeated loading (or variation of load), causes a material to break at a stress below the static breaking stress.

(c). Stresses too complicated to be calculated with accuracy may be imposed.

(d). Defects may exist in the material or due to workmanship.

(e). Liability to unforeseen or extraordinary stresses.

If we possessed sufficient data, properly interpreted, the elements of doubt due to (a) and (b) could be eliminated; and designs could be made not upon the basis of the breaking stress under a load applied only once, but upon the stress which could be indefinitely repeated without rupture or production of any considerable permanent distortion. The element (c) can only be removed by a more perfect knowledge of the effect of all forces applied to a member. When such advance has been attained there remain but the two elements of uncertainty; possible defects, and unusual contingincies, to be provided for. A margin to cover these would still be necessary, but reasonable allowance for them, in ordinary cases would give a comparatively small factor of safety, or contingency factor, as it might be called.

The remainder of this article will be devoted to a few illustrations intended to indicate the weight of one of these various elements of our so called factor of safety. The data for these examples is drawn from Unwin's Machine Design, Part I. On page 24 of this work (twelfth edition), will be found a table of factors of safety, from which the following are taken: Case I; for variable stress of one kind only, cast iron—6; wrought iron—5. Case II; for equal alternate stresses; cast iron—10; wrought iron—8. From table I, page 40, we select:

Cast iron—ultimate strength, 17,500 pounds per square inch.
*Cast iron—elastic strength, 10,500 " " " "
Wrought iron—ultimate strength, 57,600 pounds per sq. in.
Wrought iron—elastic strength, 30,000 " " "

*Cast iron has no well defined elastic limit.

On page 32 there are some empirical formulas representing the results of Wöhler's researches upon the effects of repeated loading.

Case I—Load removed and applied indefinitely, but stress of one kind only :

$$k_{max} = 2\left(\sqrt{n^2+1} - n\right)K.$$

Case II—Alternate tensile and compressive stress of the same magnitude ;

$$k_{max} = \frac{1}{2n} K.$$

In which K is the static breaking stress ; k_{max} is the breaking stress when subjected to indefinite repetitions ; n is a constant, taken at 1.5 for ductile materials, and 2 for hard qualities.

Substituting the values n as given above, we derive for the two materials under the conditions considered above :

Cast iron—Case I, $k_{max} = 0.48\,K.$
Cast iron—Case II, $k_{max} = 0.25\,K.$
Wrought iron—Case I, $k_{max} = 0.6\,K.$
Wrought iron—Case II, $k_{max} = 0.33\,K.$

Introducing the values of K, as given above for cast iron and wrought iron, we derive from the data taken :

Cast iron—Case I,	$k_{max} = 0.48 \times 17{,}500 = 8{,}400$	lbs. per sq. in.	
Cast iron—Case II,	$k_{max} = 0.25 \times 17{,}500 = 4{,}375$	"	" "
Wrought iron—Case I,	$k_{max} = 0.6 \times 57{,}600 = 34{,}560$		" "
Wrought iron—Case II,	$k_{max} = 0.33 \times 57{,}600 = 10{,}200$		" "

The values just computed would represent the maximum working stresses if it were safe to work up to the stress at which rupture eventually occurs ; if there were no possibility of the elastic limit being passed at this stress ; or if no provisions were necessary for defects, and other contingencies. Dividing the appropriate ultimate static stresses by the stresses just computed, we get the corresponding partial factors of safety as follows : Cast iron—Case I, 17,500 ÷ 8,400 = 2.1 ; Case II, 17,500 ÷ 4,375 = 4 ; Wrought iron—Case I, 57,500 ÷ 34,560 = 1.67 ; Case II, 67,600 ÷ 19,200 = 3.

Now referring to the factors of safety as quoted from Unwin, and dividing each of these by the corresponding partial factor as just found, we have : Cast iron—Case I, 6 ÷ 2.1 = 2.86 ; Case II, 10 ÷ 4 = 2.50 ; Wrought iron—Case I, 5 ÷ 1.67 = 3.0 ; Case

II, $8 \div 3 = 2.67$. That is, a factor of only $2\frac{1}{2}$ to 3 is provided for protection against all such contingencies as: possible permanent distortion; defects in fitting which may produce unequal distribution of stress; unreliability of material due to original flaws, cooling stresses, effects of maltreatment (mechanical or thermal); actions not considered in the calculations; overloading from any cause whatever, etc.; and all effects, in short, except those due to repeated loading.

The importance of a knowledge, upon the part of the designer, of the methods employed in the manufacture of a material which he uses, and of the practice of the shops in which his designs are executed, is appreciated, when we reflect that these things all have a direct influence upon the proper factor of safety. As the methods of the metallurgist insure a more reliable and homogeneous product, and as methods of inspecting materials are perfected, the danger from hidden defects in the material furnished becomes smaller; as artisans become more accustomed to the properties of the material which they handle, and learn to respect its weaknesses; as investigators develop the effect of repeated stresses, of the various kinds; and as the engineer learns to study all of these elements and to give to each its due weight; the factor of safety will be reduced, it will become less and less a factor of ignorance, and more and more a true factor of safety.

It appears from our discussion that if a factor of safety of 10, for example, is necessary, it does not by any means follow that the piece must be ten times as strong as theory would indicate. The fault is not with the theory but with our incomplete stock of it; and when the theory of the factor of safety has received the attention that has been given to other elements of design, we may hope to descend more systematically and reliably in our parachute. In the mean time we should analyze each case as carefully as our knowledge will permit; consider all conditions before choosing a factor of safety, remembering the text with which this discourse began: "The capacity to choose the proper factor is *the* important point in machine design."

NOTES ON THE MATERIALS OF AERONAUTIC ENGINEERING.*

BY R. H. THURSTON.

"The most urgent demand for strong materials of construction comes from the designers and builders of machinery which must be transported, and especially when it must take part in its own transportation—as in the case of the locomotive and the marine engine—while the lack of still stronger materials than those we now are able to produce is one of the greatest difficulties to-day obstructing the engineer and the mechanic in the endeavor to enter upon a new and most attractive field—that of aeronautics.

"No matter how ingenious the inventor or skillful the maker, aeronautic progress is impossible (except floating by aid of supporting balloons) until propelling machinery can be produced powerful enough to lift and impel itself and its enclosing air-ship; or, otherwise and perhaps better stated, until such machinery can be built light enough to sustain itself with its load, with a large reserve of lifting and impelling power."

The express locomotive weighs 100 or 150 lbs. per H. P. and takes several times its weight along the rail at from 50 to 80 miles per hour; the marine engine, occupying one-fifth the space of the containing vessel, weighs from 500 and 600 down to 200 and 300 lbs. per H. P.; while torpedo-boat, and fast yacht machinery weigh in many cases as little as 100 lbs. per H. P,; but these are all vastly higher than the maximum weight required by the aeronaut. The birds weigh certainly no more than 20 or 25 lbs. per H. P. and man must rival and surpass them. Machinery weighing 25 lbs. per H. P. is probably the practical limit.

A good draft-horse weighs about 1500 to 2000 lbs. per H. P. Strong men work at about the rate of 1 H. P. per 750 lbs. weight as a minimum and not far from double that figure as a maximum. The animal's muscular substance is subjected to a maximum stress of not more than about 100 lbs. per sq. inch, in ordinary work 15 or 20.

Mullenhoff reports the stress per unit section of a bird's muscles as about ½ to ¼ kilogram per sq. centimeter or not far from

*An abstract of a paper read by Prof. Thurston before the World's Columbian Exposition Engineering Congress at Chicago, 1893.

15 to 20 lbs. per sq. inch. Pénard, on the other hand, gives the resistance of a feather as about 45,500 lbs. per sq. inch, about the strength of the softer grades of bar and sheet iron. But its density is about 1/3; thus making its value for aeronautic purposes very great, giving 6 times the carrying power per unit weight.

By comparing these figures with those given by the authorities for the actual stresses on the muscular fibre, the animal machine would seem to have a very high factor of safety.

"It is most wonderful that, with these low stresses, with high factors of safety, and with comparatively bulky and weighty fuel, these animal machines should be able to lift into the air a load equal to 50 per cent. of their own weight, and, unloaded, to traverse a thousand miles without stop in a day. It seems very probable that a weight of somewhere about 10 or 12 lbs. per H. P. for the machinery of propulsion must be worked for if success is to be either certain or satisfactory in this particular detail of the problem which the aeronaut seeks to solve as a would-be 'aviator.'

"This reduction of weight may be accomplished by advances in either or all of three directions: (1) Reduction of weight of material by improved design and proportions; (2) increase of ratio of strength of the materials used to their density; (3) increased velocity of motion of the moving parts of the machinery transmitting energy.

"By careful selection and ingenious combination of the lightest and strongest available materials, Stringfellow, Henson and Hargreaves have produced machinery of the minimum weight, and the prize engine of the British Areonautical Society weighed but 16 lbs. per H. P.; that of Maxim, built of tempered tool steel, weighs, with its boiler, less than 10 lbs. per H. P.; and the engines of Langley, without boilers, are similarly reduced in weight to 6 lbs. per H. P."

Of the two factors which produce the resultant energy in any case of application of power to useful purposes, force and velocity of motion of the point of application of the force, that which is most desirable from the stand-point of the engineer is velocity, since an increase in velocity affects weight, strength and cost of construction comparatively little. The first necessity therefore is to secure such a design as will give the largest practicable value to the velocity. When this is done there remains the possibility of reducing the ratio of weight of machine to power developed

by reduction of the weight of each element of the machine to the smallest quantity capable of sustaining the effort transmitted by it ; reducing the ratio of density of material to strength while, it must be remembered, retaining also so much of ductility as is required to insure safety through that resilience which must be present to meet the action of blows and shocks. It is not enough that the material chosen is strong nor is it sufficient that it shall be light.

"Steel is three times as heavy as aluminum, but it may be given from four to five times its strength, and is much the better material, so far as we can now see, for aerial constructions. The metal weighing 480 lbs. per cubic foot will sustain, in its strongest form, perhaps 100,000 ft. of its own substance ; while the metal weighing but 160 lbs. per foot can uphold only about 25,000 ft. in the form of a suspended bar, or about 60,000 ft. in fine wire. This last is the true gauge of the constructive value of the metal, as of any other substance to be used as a tie. The height of the column which will stand without crushing or bending is the similar gauge of the value of the substance in compression and the span of a standard form of girder which would just sustain itself—that for transverse loading.

"The following figures permit this sort of comparison to be made among the various familiar metals of common use in machine construction, as given by Messrs. Hunt, Langley and Hall.

DENSITY AND WEIGHT OF METALS.

METAL.	Weight of 1 cu. ft.	Tensile strength per sq. in.	Length of a bar that just supported its own weight.
Cast iron	444 lbs.	16,500 lbs.	5,351 ft.
Ordinary bronze	525 lbs.	36,000 lbs.	9,874 ft.
Wrought iron	480 lbs.	50,000 lbs.	15,000 ft.
Hard struck steel	490 lbs.	78,000 lbs.	22,922 ft.
Aluminum	168 lbs.	26,000 lbs.	22,285 ft.

"It is seen that the value of aluminum for purposes demanding maximum strength per unit of weight is substantially the same as that of steel having a tenacity of between 75,000 and 80,000 lbs. per square inch, while both metals are superior to the others in the list and 60 per cent. better than wrought iron, the next best in the catalogue."

"The limiting value of the materials of aeronautic construction may be assigned by reference to the fact that thus far only the fine steels have been considered sufficiently strong and light to permit the construction of machinery for such purposes. Their cost, when thus employed for all the working parts, and in forms giving maximum strength with minimum weight, is very great; but this is a comparatively unimportant matter for present purposes. Such steels are capable of sustaining their own substance in lengths of from 25,000 to above 100,000 ft.; and we may take the former figure as our limiting value. Any material incapable of sustaining 25,000 ft.—about five miles (7,606 meters)—of its own substance in a pendent bar may be ruled out of the list of those which promise to be of special service in future aeronautic construction.

"Similarly, any substance thus incapable of sustaining about 15,000 ft.—three miles (or 4,600 meters)—without exceeding the elastic limit of the material at the point of suspension, may be also discarded from the list. Still another gauge of the value of the material is the quotient of its tenacity by its density. If the tenacity in pounds on the square inch, divided by the weight in pounds per cubic foot, is less than about $\frac{t}{w} = 150$, it is not wanted; or if the quotient, elastic resistance divided by weight is less than $\frac{e}{w} = 100$, it will not suit such purposes.

"The limiting value is, in fact, in most cases, if not in all, the elastic limit of the material. The elastic limit of the substance never has the same relation to the ultimate strength in any two materials. In the softer metals, as in copper, tin, lead, zinc, there is no definite elastic limit until one has been produced by load, the metal stretching sensibly with every sensible load, however small. Iron and steel have a definite elastic limit at their first loading; but it rises with every load in excess of the 'primitive' elastic limit, until finally the elastic limit coincides with the ultimate resistance, and the piece then breaks without the occurrence of extension marking the separation of the two critical points now united."

Fiber and other organic substances promise great usefulness in the construction of some form of aeronautic apparatus, and have in fact, in ballooning, been the only forms of material meeting the requirements of that branch of engineering work. Of the

available forms of fibre, silk, hemp and glass, with perhaps in some cases, cotton, are the kinds employed.

Hemp, iron and steel rope weigh respectively according to Clark, 3, 2, and ½ lbs. per fathom, for a breaking load of about 6000 lbs. Their breaking lengths are, on this rating, 12,000, 18,000, and 24,000 ft., and they will sustain without exceeding their working loads, 2,000, 3,000, and 4,000 ft. respectively. On this rating hemp would not answer our purpose.

Braided linen, "silkworm gut" or "sinew," and "cat gut" are some of the strongest fibers. They have about the value of steel at a tenacity of 115,000 to 125,000 lbs per sq. inch and less than one-half that strength which is attainable in the latter sections similar to those of these natural fibres. We find nothing in nature that can compete for present purposes with the finest steels in the form of the finest wire and thinnest ribbon or sheet. No natural substance can be found as yet which can approach the rival metals in hardness and safety against injury by shock or abrasion, both of which qualities are of great importance.

The fabrics woven of the above mentioned fibres have substantially the same rating as the fibre of which they are composed. But these fabrics may sometimes have peculiar value for special purposes, such as for the covering of balloons and the construction of aeroplanes, and may prove more useful than the otherwise superior metals.

"The woods, combining as they do lightness, stiffness and considerable strength, are often found the very best of all the materials of construction where this combination of qualities is important. Some of the most successful of all attempts to construct aeronautic apparatus have been the result of skillful application of the strong, stiff and light woods in their production Bamboo, ash, spruce and the pines most free from pitch have been found especially suitable."

Several tables are available showing the co-efficient of tensile and compressive resistance of the woods common in our markets.*

The densities, and weights per cubic foot of the woods vary from .5 to 1.2 and from 30 to 80 lbs. respectively, according as they are light and well seasoned on the one hand, and heavy and green on the other. For aeronautical purposes all timber should have been at least a year seasoning and should be so treated when in the structure that it cannot absorb moisture.

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* *Vide* "Materials of Engineering" Thurston Vol. 1.

"The relative resilience of timber is given by Haswell as below:

Material.	Value.	Material.	Value.
Ash	1.0	Larch	0.84
Beech	0.86	Oak	0.63
Cedar	0.66	Pitch Pine	0.57
Chestnut	0.73	Spruce	0.64
Elm	0.54	Teak	0.59
Fir	0.40	Yellow Pine	0.64

"The same authority gives the following as the relative values of the woods under compression in long columns:

Material.	Value.	Material.	Value.
Ash	3,571	Oak—Quebec	2,927
Beech	3,079	Spruce	2,522
Cedar	700	Sycamore	1,833
Elm	3,468	Teak	3,555
Oak—English	4,074	Walnut	2,378
Mahogany	2,571	Yellow Pine	3,193

"Cast iron, oak and pine have the relative standing, irrespective of weight: 10,000, 1,088, 785.

"The weights per cubic foot and the densities of seasoned woods of most promise for light and strong constructions are the following:"

Material.	Specific Gravity.	Weight per cu. ft.	Material.	Specific Gravity.	Weight per cu. ft.
Ash	.69	43	Mahogany—Spanish	.72	45
Beech	.66	43	Oak—White	.76	43
Birch	.57	35	Oak—Live	1.07	67
Cedar	.56	35	Pine—White	.42	29
Elm	.57	36	Pine—Yellow	.54	34
Fir (Norway Spruce)	.51	32	Spruce	.50	31
Hemlock	.37	23	Sycamore	.62	39
Hickory	.69	43	Walnut—Hickory	.67	42
Lancewood	.72	45	Willow	.49	37
Mahogany—Honduras	.56	35	Yew	.80	50

A study of the tables of figures bearing on the subject shows that the woods of a better class generally may be taken as equivalent to the steels of the strongest classes for such purposes as the former best suit.

It is evident from a survey of the more familiar metals that lead, tin, zinc, and copper, are too weak in proportion to their weight, to serve as materials of aeronautical construction except under such circumstances as to compel their use in spite of their unsatisfactory tenacity.

"Steel castings seem likely to prove peculiarly valuable for use in the framework and massive parts of machinery in which lightness is important. Those made for use in ordnance construction, as for gun carriages, are expected by the Ordnance Bureau of the United States War Department to have a tenacity of not less than 65,000 lbs. per square inch. with a ductility not less than 20 per cent., and not less than 55,000 lbs. tenacity; and 15 per cent. elongation in test pieces four diameters long condemns the metal. Castings weighing three or four tons have been made to these specifications and given tenacities exceeding 70,000 lbs. and elastic limit of above 30,000 lbs., with elongations exceeding 33 per cent. and a contraction in area of above 45 per cent. Such metals, especially in castings of parts often difficult to otherwise form, gives promise of becoming enormously valuable in locomotive, marine engine, and aeronautic work. Comparing them with sound aluminium, we find that they be made to sustain a length of about 25,000 ft., have a ratio of tenacity to heaviness of about 140, and if, as is perfectly practicable, giving somewhat greater hardness and strength for aeronautic than for other construction; and especially as they will usually be employed in small parts or in parts having small sections, they may, by Whitworth's or other method of solidification, be made of considerably higher value than even the above figures would indicate.

"Whitworth, with a compression of the solidifying casting under about 20 tons per square inch pressure, obtained castings ranging from 80,000 to 150,000 lbs. tenacity, with elongations ranging from 35 to 14 per cent.

"Similar figures may be obtained by drop forging, and it may be confidently anticipated that the rapid improvement now in progress in the manufacture of this class of metals will soon give us maximum tenacities in masses of large as well as small section, and bring that maximum up to and above the highest yet attained

in the smallest sections. It is to-day possible to secure such castings as the above with a ratio of tenacity to weight of from 150 to 300, and capable of carrying a length of their own sections not less than 25,000 and possibly as great as 50,000 ft., and from equality with aluminium up to twice its value. Such castings are, therefore, to-day available for the frames and cylinders and other stationary and intricate parts of the machinery of aeronautics, such as cannot as a rule, be practically and economically made of the forged metals."

Aluminium, from which great things have been expected in aerial navigation has a density of 2. 6. It melts at about 1200° F., passing through a pasty stage, like wrought iron, above the red heat. It can be welded either cold or at temperatures between 200° and 400° F.

Cold rolling, hammering and wire drawing harden and strengthen the metal greatly. Sometimes doubling its strength and making it equal to steel of 150,000 lbs. tenacity.

Its coefficient of expansion is high, being nearly double that of iron, a fact which may prove of disadvantage when the metal is exposed to irregular heating.

Alloyed with copper, titanium or silver, its strength is increased by even very small doses to, in some cases, double that of the unalloyed element. These alloys also have high conductivity—a very important matter if, as seems not at all improbable, electrodynamic machinery may at some time be used for aeronautic work

The Alloys of Aluminium has been as yet comparatively little studied with the exception of the bronzes in which the lighter metal is substituted for zinc or tin. Aluminium wire can, it is stated, be already supplied at a tenacity of 60,000 to 70,000 lbs. per sq inch and of a ductility measured by a reduction of area of 50 per cent. Alloys are predicted having double the former tenacity and with a density not exceeding 3.5.

"Aluminium is often introduced into iron with advantage, apparently acting mainly as flux, as it disappears to a very large extent in the working of the metal, and its purifying action is the main indication, in the finished material, of its earlier presence. It is added in the bath in the puddling furnace in the manufacture of wrought iron immediately before the iron "comes to nature;" it is introduced into the fluid mass in steel making immediately before tapping off, and it is thrown into the cupola at the last moment before pouring in purifying cast iron. From

one-half to two-thirds of the aluminium is lost in the operation, and from one-half to one-third is found in the iron or steel. The admixture is usually about 0.1 of 1 per cent. The gain by its use is stated to be sometimes as much as 20 per cent.

"Aluminium bronzes are usually alloys in which the tin of common bronzes is displaced by aluminium. The percentages of the lighter metal are commonly between 5 and 10; but both larger and smaller proportions have their special values for specific purposes. Their densities range from 8.5 for the "2½ per cent. bronze," to 8.25 for the "5 per cent. bronze," and to 7.6 for the "10 per cent. bronze" as cast. The worked metals rise in density to 8.6, 8.3, and 8.85. The best known and most used alloy is the 10 per cent. alloy, which has, when sound and pure, a tenacity of about 120,000 lbs. per square inch, an elastic limit at about two-thirds this figure, and an elongation in standard tests of from 25 to 30 per cent., with reduction of minimum section from 25 to 40 per cent. In castings its strength is usually a third less than the above, and its ductility less in an equal proportion. The modulus of elasticity is in the neighborhood of 18,000,000 lbs. In compression, its resistance is from 150,000 to 160,000 lbs per square inch. With 5 per cent. aluminium the alloy has about three-fourths the strength above given and 50 per cent. more ductility. These alloys can be forged like wrought iron or steel, at a full red heat, and are unaffected by high temperatures. Aluminium and its alloys are annealed by slow cooling.

"The introduction of copper into aluminium increases its density slowly and its strength rapidly. Each 1 per cent. raises the density about 0.025, the computed increase being 0.06 and the tenacity one-third; 6 per cent. copper giving an alloy of double the tenacity of the pure aluminium, and put 5 per cent. increased density.

"The maximum effect of the dosing with copper is seen to be found at about 6 per cent. copper, 94 aluminium. It is, however, possible that other changes may occur at other proportions as yet unstudied. The quotient of the tenacity by the weight per cubic foot being, for the best alloys here given, about 300, it is obvious that they may serve our purposes better than the pure metal and even better than steels of above 120,000 lbs. tenacity. The 6 per cent. alloy will sustain a pendent length of its own substance of about 40,000 ft. or nearly eight miles."

Magnesium, although still a rare metal and somewhat costly, has always seemed to the writer of this paper, a possible rival of

the more common metals for light construction. It is lighter than aluminium, its specific gravity being, 1.74, but its tenacity is only 22,000 to 32,000 lbs. to the square inch; so that it would sustain from 28,000 to 42,000 lineal feet of its own substance. It seems more likely therefore, as in the case of aluminium, to prove more serviceable in alloys than pure; but although the writer has been experimenting with the metal for about thirty years he does not know of any of its alloys which would be valuable for aeronautic constructive purposes.

Manganese, chromium, nickel and silicium have also found application in the arts as alloys both in bronzes and in some varieties of steel. They impart to the latter various qualities, such as increased toughness, hardness, resistance to penetration, etc., but without very materially increasing its tenacity, so that for a beginning at least they cannot be said to be superior to carbon as an alloy for steel intended for aeronautic constructions.

"Conclusions from what has preceded seem very clear and unquestionable as far as the most important matter in hand is concerned. Steel is, for general use, the most promising of all materials yet known:

"For the motor machine of any system in which lightness is a primary object and strength even more essential than in ordinary construction, the form of the machine must, first of all, be such as involves the employment of tension and compression members as exclusively as practicable, and the entire elimination of every unessential beam or girder; this being the way to secure the highest effectiveness of whatever materials are available. It is usually possible to construct designs in which no other parts than shafts and pins shall be subject to cross-breaking stresses. Frames and running parts may be made of steel; and ties of the best forms for strength combined with minimum sections and volumes. Even irregular parts, such as steam cylinders, may sometimes be built up of malleable material of maximum value, constructively. Drop forging and castings of steel as high in carbon or other hardening and strengthening elements as is consistent with needed malleability and ductility are better than even any form of aluminium alloy yet discovered, probably better than any alloy of magnesium, where irregular and unmalleable shapes are demanded. Fine steel wires and ribbons having a tenacity of 300,000 lbs. or more per square inch, and thin steel tubes of nearly equal strength, represent the highest result yet attained in uniting the two essential properties.

"Among the possibilities we are apparently to look for improvement by the introduction of manganese and nickel, although we can as yet see nothing very promising in either direction. Of the two, nickel appears to offer the best results. We can see nothing of value among the alloys of the familiar metals--copper, tin and zinc. We know what is the character of the best possible combination, and that no alloy of these metals is possible possessing unknown properties. We have detected the "maximum alloy," and have learned its properties. It cannot compete with steel in the principal parts of such machinery as we have in view.

"Of the rarer metals, aluminium has been expected to give a great advantage; but we find it far inferior, both in itself and in all its known alloys, to even common steels. Magnesium, a still more promising but much less well-studied metal, gives evident promise of competing successfully with aluminium, both in lightness and strength and in the combination of the two qualities, for such machinery.

"For the hull of the air ship, and for other vessels requiring similar properties, it seems very possible that some such substance as the paper employed for racing boats, perhaps even some of the aluminum and other alloys, or those of magnesium perhaps still more possibly if not probably—substances which combine a certain stiffness and substantiality with lightness, and adapt themselves especially to the production of such forms of construction, may answer the purpose. This is quite a different matter, and time and trial only can decisively settle this question. It would at the moment, however, seem probable that steel in thin sheets will prove unrivalled for even such parts as these, and the gist of the whole matter may be summed up in the statement that steel, in its various known grades and qualities, is to-day the one unrivalled substance for all constructions, and that the problem of the moment is the finding of simple and cheap methods of forming of that metal the parts and shapes desired without loss of its wonderful combination of strength, ductility, resilience and comparative lightness as illustrated by the best qualities known, and at present only in small sections. That is to say, we have yet to learn how to secure the real, the intrinsic—if I may use that word—the intrinsic strength and resilience of the metal in all forms and in whatever mass may be demanded."

Meantime whatever the outcome of our, as yet incomplete or unattempted researches in these fields, we have the privilege of asserting that even with known materials and known methods of

construction of familiar designs, the problem of motive machinery is practically solved, and that we can to-day build motors of steel that excel those of nature, whether of fish, beast, or bird, in their combined lightness, power and compactness. The problem of aviation even is no longer one of weight and power of motor; although it would be folly to assert that there is not much to be done in that direction. Should it prove ultimately possible to construct the air-ship and its various accessories we may now feel sure that it will not be that hitherto apparently greatest of all visible obstacles, the prodigious weight of motor-machinery as compared with that of the birds, which will impede progress. The problem for the hour is now, for aeronaut and aviator alike, that of the construction, and especially of the management of the hull and of the propelling wings or screws of the floating or the self-supported air ship.

SELECTED ABSTRACTS OF SEMINARIES IN MATERIALS OF CONSTRUCTION.

BY MEMBERS OF CLASS OF '95, UNDER PROFESSOR BARR.

KARTAVERT.

BY T. H. SAVERY, JR., AND R. B. LEWIS.

Kartavert, as the name signifies, is changed paper, the word being derived from the two Latin roots:—Charta—paper; Verto—to change.

This article is an outgrowth of a long series of experiments that have culminated in an unqualified practical success, and is a great improvement over all fibrous materials of its class. It may be defined as a highly refined fibrous substance, which by numerous chemico-mechanical processes, is given a degree of toughness and durability unequalled by the various mineral, vegetable or animal products, adapted to similar purposes. This material is manufactured by The Kartavert Manufacturing Company, who operate an extensive plant at Wilmington, Delaware. Their process is, briefly, as follows:—A special quality of cotton fibre paper is obtained in large rolls, which are placed at the front of the machine, and upon unwinding pass over a drying cylinder. This cylinder is heated by steam and is kept at such a temperature that the paper is soon dried. It then enters a bath of chemicals

immediately back of the dryer. This bath contains the secret and patented parts of the process. The action of the chemicals upon the paper causes a change in its surface and general texture such that each fibre becomes glutinous. The change takes place quickly, a given portion of the paper passing through the bath in less than a minute. While in this condition the paper passes to another cylinder or dryer upon which it is rolled and pressed. This cylinder is slightly heated with steam, and the paper drying as it is wound up, is converted into one homogenous mass termed Kartavert. This winding continues until the sheet is of the proper thickness, usually spoken of as 1 to 80 ply. While in this green or uncured state the thickness of the sheet must be twice that finally required, because during the curing and drying processes the sheet shrinks in thickness fifty per cent.

This sheet of proper thickness continually submitted to pressure is allowed to revolve, until sufficient time has been allowed for the chemical actions to take place. Then by means of a peculiar knife, operated by a windlass and sliding along a groove in the face of the cylinder, the sheet is cut in a straight line across its entire surface and is thus loosened from the form.

From the dryer the green Kartavert is taken to large vats containing water, where it is passed through the cleaning processes, in which the superfluous acids are washed out by simple contact with pure water. These acids are reclaimed and used again.

From the baths the sheets are taken to drying rooms, which are heated by steam passing through pipes forming the entire floor. While here they warp and twist so that it becomes necessary to straighten them when removed, which is done by pressing or rolling processes. These finished sheets now vary from $\frac{1}{100}''$ to $1\frac{7}{8}''$ in thickness but are of uniform width and length.

The color of Kartavert is either Indian-red, white, or black, depending upon that of the paper used in its manufacture. It is claimed that Indian-red is best for most purposes, and it is generally used; while the white and black are used entirely for certain articles, for which they seem especially adapted. The surface of Kartavert is susceptible of a beautiful finish and is well adapted for use in the manufacture of ornamental articles.

From the straight sheets and tubing, Kartavert is made into various articles, the material passing through almost the same processes as would be used in making similar articles of iron, except that Kartavert cannot be moulded. It can be worked in a lathe, drilled, riveted, sawed, and punched. It can be fitted with sharp screw threads, receiving a very smooth finish.

Kartavert may be classed among the hard fibres, but for evenness and smoothness of texture and other qualities it is far superior to any other material of its kind. It is of two kinds, *hard* and *flexible*. The hard variety holds an intermediate position between the metals and various ebonites and plastics. In its physical properties it somewhat resembles horn; in some other respects it resembles a very close-grained sole-leather, this being especially true of the flexible material. It is very strong and tough, is not easily fractured by a blow, resists enormous compressive strains and retains its elasticity under all ordinary temperatures. Because of this remarkable toughness and strength, which admits of its being forced into any position without breaking, it is far superior to hard rubber for most uses to which that substance is applied. It is insoluble in hot or cold water, benzine, turpentine, oils, ether, bi-sulphide of carbon or other solvents. Acids and alkalies affect it but slightly. It resists the entrance of oils, does not ignite readily, and withstands a high degree of heat. Kartavert has practically no cleavage nor stratification, and withstands considerable tension. The insulating properties of the substance have been well tested; it is found to be an excellent non-conductor of electricity, a perfect insulator in all dry places, and is also much cheaper than hard rubber and improves with age, for which reasons the economy of using it is apparent.

Among its many uses Kartavert is especially applicable to the construction of dynamos and motors; as field and commutator rings, collars, washers, bushings, and in the winding of armatures; in switches, incandescent sockets, arc lamps, combination and electric fixtures, telephone, and minor appliances; for insulating cleats, friction and intermediate gears, friction clutches, brake-shoes, rollers, powder press plates, gibs for engine cross heads, trunks and cases; and as a substitute for raw-hide on textile machinery.

As an adjunct for practical and applied mechanics, Kartavert has already obtained for itself a place heretofore occupied by products defective in composition and unreliable in application to the verge of uselessness. Of this material it may truthfully be said:—Its full extent of usefulness remains undiscovered but indications point to an almost unlimited and boundless field

HEAT UNITS DEVELOPED IN A BLAST FURNACE.

BY H. A. BOYD.

In determining the amount of heat developed in a blast furnace, every part of the furnace and charge capable of storing heat, besides the actual heat derived from the fuel, must be taken into consideration. In order to consider the development of heat, we will assume a blast furnace with the following measurements :

Stock line, 17′ ; boshes, 12′ ; height, 80′ ; and that it has a daily output of 200 tons of pig-iron. Also that the ore contains 60% iron and 12% silica, and that it will require 1.6 tons ore and .4 ton flux to make one ton of iron. If it requires a ton of coke to make a ton of iron, and coke contains 10% ash, then it will require an additional amount of .15 tons flux. To produce one ton iron requires,

Ore	1,6	tons.
Flux	.4	"
Coke	1.	"
Flux for coke . . .	.15	"
Total =	3.15	" solid material.

It requires about 160,000 cu. ft. of air to produce one ton of iron, which would be at the rate of

$$\frac{160,000 \times 200}{24 \times 60} = 22.222 \text{ ft. per minute.}$$

The air for one ton of iron will weigh 5.81 tons, which makes a total of 8.96 tons of material charged into the furnace to produce one ton of iron. Therefore ($200 \times 8.96 =$) 1792 tons pass through the furnace in one day.

The flux used is limestone, containing 2% silica and 1% alumina. The furnace will produce .575 tons slag per ton of iron, or 115 tons slag per day.

Summing up, we get the total charge into the furnace per day to consist of 320 tons ore, 200 tons coke, 110 tons flux, and 1162 tons blast, amounting in all to 1792 tons. The total tapped from the furnace in a molten state is 315 tons, of which 200 is iron and 115 slag. The gaseous product which escapes from the top of the stack weighs 1477 tons, distributed as follows : Blast, 1162 tons ; oxygen from ore, 96 tons ; carbon, as CO and CO_2, 161 tons ; carbon from flux, 49.95 tons ; volatile matter, 8.05 tons.

The heat energy developed, and more or less wastefully consumed, is enormous. In 24 hours fully 5,000 millions of heat

units are developed, which, if properly utilized, would develop over 8000 horse power.

The average amount of solid and molten matter in a furnace of 200 tons daily capacity is not far from 600 tons. If the heat were equally distributed through the mass, the average temperature would be about 1600°. The charge becomes denser as it gets lower in the stack, and 2000° is probably the average temperature of the solid molten material, the temperature at the hearth being about 3000°. The specific heat of this mass is not definitely known, but may be taken as .25.

We get for heat stored up in the incandescent furnace stack,

Tons.	Lbs. in Ton.	Temp.	Sp. ht.	
600 ×	2000 ×	2000° ×	.2.5 =	600,000,000 heat units.

The lining of the furnace will weigh 800,000 pounds, and the specific heat of fire brick at a temperature of 1600° is not less than .18. We therefore have for heat stored in the lining,

Wt. of brick.	Av. temp.	Sp. ht.	
800,000 ×	800 ×	.18 =	115,000,000 heat units.

The blast should be heated from 1200° to 1400°, and for this purpose three hot blast stoves are used. They contain about 35,000 cu. ft. of fire brick, which, at 150 pounds per foot, would amount to 5,250,000 pounds. The average temperature of brick work in these stoves, when blast is 1400°, may be taken at 1000°, and specific heat of brick at this temperature at 00.2.

	Wt. brick.	Temp.	Sp. ht.	
Then we have	5,250,000 ×	1000° ×	.25 =	1,050,000,000 = the

heat units stored in the stoves.

Thus we have the following enormous quantities of material consumed and heat energy developed:

Charged into furnace *per diem*:		
Solid material at top	630	tons.
Gaseous at tuyeres	1162	"
Total	1792	"
Discharged from furnace:		
Molten material from hearth	315	tons.
Gaseous passing off	1477	"
Total	1792	"

Heat units developed from fuel used in 24 hours	5,000,000,000
Stored in lining	115,000,000
Stored in material of furnace	600,000,000
Stored in stoves	1,000,000,000
Total	6,765,000,000

It is to be noted that this last figure represents the total amount of heat generated in the *first* day's run. Obviously that stored in

the lining of the furnace and in the stoves would not have to be redeveloped on the next day.

THE ALLEN PAPER CAR WHEEL.

BY L. B. HOWELL.

A paper wheel, so-called, consists essentially of a core of heavy paper forced into a steel tire under great pressure, a hub of cast iron forced into the center of the paper core, and retaining plates of wrought iron. The object of the paper center is the securing of elasticity, and the reduction of the jarring to which the axle and journals are constantly subjected. It has been demonstrated that the effect of such a jarring in a bar of iron or steel, is a crystalization in the structure of the material, which has an injurious influence upon its wearing qualities.

The process of manufacture, as observed at the works of the Allen Company, at Pullman, Ill., is briefly as follows: The core is built up of strawboard paper discs about $\frac{3}{16}$ inches thick, glued together in sufficient numbers to give it the required thickness. The core is then subjected to 800 tons pressure for one hour. At the end of that time it has become practically a homogeneous mass and can be turned to the proper size to fit the steel tire, into which it is forced by hydraulic pressure varying from 90 to 120 tons, according to size of wheel. Thirty tons pressure is required to force the cast iron hub into place in the center of the core, and it then remains simply to bolt the retaining plates into position and to shrink the completed wheel on the axle in the ordinary manner. The product thus obtained is one, which, for durability, safety and elasticity, is unsurpassed.

As to durability, a few comparisons with the records of others will quickly show the superiority of the paper wheel. The average mileage of the ordinary type of cast iron wheel with chilled tread, is not over 55,000; steel tired wheels with other than paper centers have made as high a mileage as 200,000. This is far from the average, however. Paper wheels ordinarily have a life of about 500,000 miles, but often run much further. A pair of wheels is now in the possession of the Allen Company which holds the record at 889,424 miles.

The Allen wheel is used under all cars sent out by the Pullman company. Its cost is necessarily much greater than that of the iron wheel but this is more than compensated by the longer life and immunity from accidents possessed by it.

THE HARD ROAD OF SELF INSTRUCTION IN ENGINEERING.*

BY ANGUS SINCLAIR.

The lecture was intended to point out the value of the advantages offered by a technical education, as appears from the standpoint of a practical man, "practical" being used in the sense in which it is so often employed to distinguish between the college graduate and the one who has served an apprenticeship. Mr. Sinclair said:

"The egotistical assumption is often made that a man who works his way upward from the vise or anvil, from the fireman's scoop or from the axe of the survey, without the aids of college training, must necessarily be a better engineer on that account. Self made men are said to be peculiarly prone to worship their creator. It is very natural that a man who has climbed to a high altitude by a certain road, and has witnessed many failures by men apparently better equipped than himself, should conclude that the path which he followed was the best route. After he has rested on the summit, he forgets the roughness of the path traveled, the obstacles which were surmounted by hard tedious labor and the devious courses followed in which precious time was wasted.

"An engineer to be worthy of the name must by some means acquire a great deal of accurate knowledge of various kinds. The first requisite towards obtaining this capital of professional lore, is mental discipline, the next is guidance in acquiring the right kind of information. My own experience leads me to believe that the young mechanic who starts out determined to become an engineer, will waste no small part of his energy in the wrong direction through want of the discipline and training which an engineering school supplies. . . . .

"As a rule the engineering school graduate is strong in principles and weak in manipulation details; he ought to drop readily into the position of foreman in a manufacturing establishment, from which he would rise gradually to be a superintendent or manager. An obstacle to his success as foreman is that often he has not sufficient mechanical experience to get the work done economically. He does not know to a certainty how much work a man or machine should turn out in a given time, he does not

* Abstract of a lecture delivered by Mr. Sinclair, before Sibley College.

know whether or not a machine is worked up to its speed and capacity, and the workmen take advantage of this want of experience. The engineer who has the very best prospects of preferment to-day, is the engineering school graduate who goes into the shop and works until he can do as well as those who have been apprentices. This experience supplies a working capital which cannot be obtained in any other way.

"The fact that a young man leaves college well grounded in the principles of his future business, does not always prevent him from making serious blunders, in fact the theories emanating from the principles he has mastered sometimes lead directly into fallacies. The education one gets from practical experience often proves things to be highly successful, which theory says should not be tried.

"In practical work an engineer meets with a good many things that do not act according to the laws laid down in text books; this is particularly noticeable in the friction of different substances rubbing together. In fact there is reason to believe that many of the so-called laws have been established on insufficient data. As an example, it is generally understood that the friction between metals will be uniform when the conditions are the same; but those who have had much to do with brake shoes and journal bearings are constantly meeting with highly different results when it might be expected that there would be uniformity. Abstractly one would reason that there would be about the same amount of wear when a cast iron driving box was used with a cast steel driving wheel, as when a cast steel driving box and a cast iron wheel were used. Yet the difference is so great that cast steel boxes must be lined with a soft metal to prevent excessive wear, while a steel wheel will run against an iron box as free from wear as one made from cast iron.

"A railroad president asked me some time ago to recommend a man capable of taking charge of the machinery of one of our largest lines. He said: 'I want an educated engineer, a man who can design machinery and see that it is operated to the best advantage, but above all things I want him to be able to examine shops and tell of his own knowledge if the work is being carried on economically.' An engineering school graduate who had learned the machine trade was apparently the man for the place. He was difficult to find, but the terms of this selection ought to be an object lesson to those who are ambitious to make themselves eligible for this line of work."

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NOTICE.

Any person having back volumes of the SIBLEY JOURNAL to dispose of is requested to communicate with the Business Manager. The latter now has on file orders for two copies of March, 1893, and for Volumes I, V, and VI.

AN article has just appeared in the *Electrical World* that possesses interest for several reasons and will well repay the reader for the time spent in its perusal. The fact that it is from the pen of Henry Floy, who is familiar to the older students as a noted end-rush on our foot-ball teams of '90 and '91, lends interest to the article from the standpoint of a Cornellian; but the subject—

The Advisability of Becoming an Electrical Engineer—is an especially interesting one to a large part of the Sibley students. The writer does not present a very encouraging outlook for the prospective electrician. After citing Princeton and Cornell as examples of institutions which are models of two classes of training in electrical engineering, he discourses the situation that confronts the young man upon graduation. In the first place he must start at the bottom, below the ones who went into the shop at the time when the collegiate began his University course, and for a time he must compete with the latter on the same ground. The writer asserts, however, that the college-bred man will in time outstrip his less fortunate competitor by reason of his superior theoretical knowledge and better trained brain. The outlook for either one is not bright, however. Neither can hope to rise very high in the profession except through influential friends or very marked ability, for the men who do so rise are an exceedingly small percentage of the immense number of the seekers for success that is being recruited annually from the vast number working up from the shops and from the students of the technical schools, the latter having over 1,200 men at the present time studying electrical engineering. According to Mr. Floy the demand for electrical engineers—men highly educated in the practical and theoretical sides of the profession—is very small, and under present conditions the supply far exceeds the demand.

There is no doubt but that the writer, in stating his views, has presented strongly one phase of the problem in which a considerable number of young men are interested, but it is apt to occur to the reader that it is possible to take a little more pleasant view of the case. While it is true that our engineering schools are annually turning out an enormous number of young men educated for electrical engineering, it must still be remembered that a large percentage of these will eventually drift into some other occupation. Also, one might ask: Are more graduating in engineering relative to the magnitude of the field than in law or medicine? Possibly there are, but the snbject will bear thought, at least.

Another article that the prospective engineer would do well to read is that by Dr. Thurston on "Electrical Engineering as a Profession," which appeared in the *Interior* for March 8. In that article the writer outlines the qualifications that must be possessed by the man who hopes to succeed in this difficult profession, emphasizing a natural ability as a mechanic, an aptitude for mathematics, an interest in natural science, physics, chemistry, and, most important of all, good judgement and business ability. Dr.

Thurston demonstrates that electricity has a bright futnre, but he also shows that only a few can attain very marked success in the profession and that they must be the ones who combine in the most marked degree the qualities named above, and have the opportunity, or can make an opportunity, to display them.

JUST now, at the time when most Seniors are engaged in the writing of their theses, and since quite a number will probably write with a view to submitting their productions in the prize competition that *Engineering News* annually offers, a word or two in regard to that contest is in order. From an article in *Engineering News* for January 5, 1893, we glean the following points as being the ones upon which particular stress is laid in adjudging the theses.

(1). They must contain matter that will be of so much permanent value to the engineering profession as to warrant their publication in a technical journal of high standing.

(2). They must be clearly, concisely, and simply written.

(3). They need not be the result of an enormous amount of work, so long as what is done, is done well.

(4). They may embody either the results of new investigations, or the discussions of old investigations.

(5). When they consist of descriptions of designs, the *reasons* for each step of the design are most important and should never be omitted.

The article contained a discussion of the theses submitted that year, in which they were divided into several classes. It was stated that frequently in the opinion of the editors, too much work is spent upon the careful calculations of stresses, etc., and that the arguments pro and con upon the practical points arising in connection with the design are often left out of consideration entirely. Another class of thesis, that embodying the searching out and compiling the existing information on a subject, was commented on as generally not being very valuable. Unless the information is widely distributed and hard to get at the results of the compilation are not likely to be valuable as an addition to engineering literature.

Every member of the graduating class of any technical school in the country is eligible to enter into this competition. The faculty of each school submit the three theses, that they regard as the best, to the editors of *Engineering News*, who in their turn pick therefrom three for the first, second, and third places and several more for honorable mention. The prize theses are

printed, as are also some of those receiving honorable mention. This plan, which has been in successful operation for two years now, is certainly a most praiseworthy one. The cash prizes that are offered ($75, $50, and $25) are much less to be desired than is the honor of winning in a competition involving so much hard work.

Cornell has been represented among the prize winners in this contest by Kuhn and Mickle of '92, who took the third prize in that year, and by Clay, who won second place in '93. It must be remembered, however, that the theses are not judged in the competition in the same manner that our faculty judges them, for *Engineering News* looks at them from the standpoint of a civil engineer. It is also true that our best theses often are not submitted on account of the expense and labor involved in preparing copies.

IN looking through the technical papers one frequently comes across comparisons between American and European railroads, and finds that the former always suffer by the comparison, especially when safety is the basis. Various reasons have been assign- for the evident inferiority of our roads in this particular. One of the correspondents to the *Railway Age* points out that in this country there are two entirely different gauges of track in use, one being 4 feet 8½ inches, and the other 4 feet 9 inches. All cars must be made to move on both, hence a severe strain and wear on the wheel-flanges results. Another writer thinks our rolling stock is top-heavy.

It is to a deeper reason than these, however, that we probably must attribute the difference. Our railroads are built to meet a much different demand and must be constructed and operated accordingly. In this country rival roads are constructed side by side, and to exist must cut expenses to a minimum by economizing in every possible way. The result is that both are run exceedingly cheeply, though at a sacrifice to safety. The prices for carrying freight are astonishingly low, being often down to .3 mill per car-mile. The railroads are even able to take away the trade from the steamboats plying on the water courses. In England much different conditions exist. The matter of obtaining a charter is by no means an easy one. Parliament carefully considers whether or not there is a sufficient amount of traffic to warrant the construction of a new road, and by so doing makes it impossible for two roads to come into very close rivalry with each other. The necessity for cheapness and strict economy is thus obviated and more attention can be given to the matter of safety.

OBITUARY.

It is with sorrow that we note the death of one of our alumni. John Lange of the class of '93 has recently died at his home in Poughkeepsie. He entered Cornell in the Civil Engineering course, but changed before graduation, to Sibley. He was a good student and maintained a high position in his class.

CRANK SHAFTS.

—In 1892, $700,000,000 were invested in this country in electric industries.—*Power*.

—An attempt is being made in Cambridge Mass. to establish subways for electric wires, which shall be under municipal control. It is proposed to compel all wires to be placed therein with the exception of trolleys and those for long-distance telephone service.

—The corrosion of under-ground pipes by electrolysis due to stray currents from electric street-railways, has become an important consideration in the return circuit question. It has been found that serious injury is being done to pipes and cables in New York, Boston, and other cities, and no satisfactory remedy has as yet been devised. It is thought that only by completely insulating the railway conductors from the earth can this evil effect be avoided.

—According to Edward Weston, the loss in energy which occurs in the switchboards of some of the large electric stations is amazing. He states that he had occasion recently to examine a switchboard carrying a current of 8000 amperes, in which the waste due to badly fitting joints in the board and faulty arrangement of the station ammeters, figured up nearly $5000 a year. He mentions a single ammeter which was found to require $89 worth of energy per year to run it.—*Engineering Magazine*.

—The application of the metal aluminum in the construction of boats, about which so much was said at one time, has proved to be not a practical success. Just now, however, the navy department is conducting a series of tests upon some aluminum life-

boats that have been constructed for the service recently. The reports of the tests are very favorable to the boats tried. Their ability to resist capsizing, to right themselves if capsized, to support heavy loads, and to free themselves of water, were found to be entirely satisfactory. The boats are 18 feet long by 4 feet beam and 2 feet deep, weighing 350 pounds. They have been built for use upon the Wellman Arctic expedition.

—In a paper presented at Chicago last summer, Professor S. B. Christy stated that he had found the distribution of wage-earning population by the tenth census to be :

Agriculture, ...	44.1	per cent.
Professional and personal, ...	23.4	"
Trade and transport, ...	10.4	"
Manufactures and mechanics, ...	20.3	"
Mining and metallurgy, ...	1.8	"

He found that this called for mining, civil, and mechanical engineers in the ratio 1 : 6 : 11, while at that time the schools were graduating the same in the ratio 1 : 4.25 : 1.11. Now, however, the schools produce them in the ratio 1 : 7.73 : 9.27.

—By far the most interesting of the different electric locomotives known up to the present time is that devised by M. Heilmann of Paris, with which interesting tests have recently been conducted on the Western railroad of France. Its length over all is a little more than fifty-two feet, and its total weight 100 tons. The steam and electric generating plant is composed of a boiler, a 600 H. P. horizontal compound engine direct connected to a six pole continuous current dynamo. Another small engine and dynamo furnish the exciting current for the larger machine.

—Dr. Thurston has just had printed a very interesting bit of engineering matter, taken from the report of the City Engineer of Providence, R. I., and has presented each member of his class with a copy. It consists of tabulated comparison of the bids which were submitted in answer to a proposal to build a pumping engine for the city of Providence, the engine being required to pump 15,000,000 gallons of water per day against a head of 180 feet. The table compares the guaranteed duties, the first cost, the annual cost, and the dimensions of the pumps, proposed by the various competing firms. It is to be noted that while the first cost varied in the different cases from $53,000 to $92,000, the annual costs of operation varied only from $20,000 to $22,500. The duties ranged from 105 to 125 millions.

On each of the eight axles of the car is placed a motor giving nominally about 45 kilowatts, or a total of 360 kilowatts, or 500 H. P. On one of the trials a load of 90 tons was hauled up a gradient of 3 in 1000, at a speed of 50 miles per hour.

—An efficient smoke consumer is a very desirable adjunct to the furnace, especially in large cities, but a device which will not only eliminate the sooty products of combustion but will extract from them certain valuable elements which would otherwise be lost, is necessary in many metallurgical processes. At the mint in Birmingham, England, the smoke is forced by a high speed fan through a tank of water, where the carbonaceous matter, sulphurous acid and metallic fumes are condensed; the residue passes on up the stack. The water when charged is drawn off and the various products are extracted, the precious metals being returned to the mint, the carbon sold for electrical purposes and the sulphates converted into a disinfectant. It is not upon special apparatus of this nature, however, that reliance is usually placed in modern metallurgical works, but upon a long series of flues, dust-chambers and finally a high stack. At the Omaha and Grant Smelting Works at Denver, the whole system of flues and dust chambers is over a mile long, connected with a stack 350 feet high, the tallest in the United States.

BOOK NOTICES.

[Revue Générale des Sciences.]

THURSTON, R. H.—*Directeur du Sibley College, Cornell University, ancien président de l'American Society of Mechanical Engineers, ancien ingénieur de la marine des Etats-Unis.*—Manuel pratique des essais de machines et chaudières à vapeur.—*Traduit de l'anglais par a Roussel, ancien élève de l'Ecole Polytechnique.—Un vol. in-4° de* 500 *pages, avec* 134 *figures dans le texte.* (*Prix :* 25 *fr.*) *Baudry et Cie éditeurs,* 15, *rue des Saints-Pères, Paris,* 1894.

Le nom de M. Thurston jouit d'une notoriété universelle ; il est l'un des représentants les plus éminents de la mécanique pratique et son laboratoire de machines du "Sibley College" est le plus

vaste, le mieux outillé, le plus richement doté qui soit au monde. Nul n'était donc mieux armé que M. Thurston pour écrire sur les essais de machines, et nul ne pouvait mieux que lui écrire le beau livre que vient de publier l'éditeur Baudry.

Il semblerait *a priori* que, depuis le temps où les ingénieurs de tous pays pratiquent des essais de chaudières ou de machines, ils doivent être parvenus à des méthodes fixes, indiscutables, acceptées par tous ; ce serait une erreur ; il n'existe pas encore de méthode-type, et les divergences sont telles dans les manières d'opérer que les tableaux d'expérience de deux machines analogues ne peuvent souvent être comparés. Nous n'avons pas besoin d'insister sur les inconvénients d'un tel état de choses ; c'est évidemment le désir d'y remédier qui a conduit M. Thurston à écrire son livre. Nous croyons qu'il y a réussi et que les ingénieurs trouveront dans son ouvrage un système d'essai qui a les plus grandes chances, d'après les travaux récents, d'être adopté dans l'avenir. Il ne faudrait pas conclure de là que ce système ne recevra pas de modifications ; à mesure que les méthodes de mesure se perfectionneront, il se transformera lui-même en les appliquant ; mais les grandes lignes resteront les mêmes et les détails seuls seront modifiés.

Le livre de M. Thurston est donc, d'après nous, un livre qui fera époque dans cette grave question des essais, un livre destiné à devenir classique et que tous les ingénieurs, tous les mécaniciens, doivent avoir entre les mains. J. POULET.

Feb. 28, 1894.

ABSTRACTS OE SEMINARY PAPERS IN MATERIALS OF CONSTRUCTION. Class of '95. Sibley College, Cornell University. 1894.

This is a mimeographed collection of abstracts of the hundred or more papers read in the Seminary of the Department of Mechanical Engineering of Sibley College, under Professor Barr, during the college year 1893-4. They relate largely to the methods of preparation of the metals employed in construction, and largely to the new additions to the list of useful alloys, so-called ; such as aluminium, and the alloys employed in substitution for the older kinds of steel. Several papers are devoted to the former, and a number to the manufacture and uses of copper, especially in electrical engineering. Four discuss boiler-work and materials ; one describes the Harvey process of making armor

plates ; and another the manufacture of heavy ordnance ; eleven consist of accounts of the manufacture and uses of the steels ; the rest are descriptions of other no less interesting and important subjects.

The papers are well written, the abstracts well prepared, and the book making most creditable to Mr. J. A. Switzer, who has edited it and supervised its publication for the class. A good index of subjects, and a long and complete list of the works of reference quoted, add greatly to the value of the book. All members of the Class of '95 and the libraries of the University and Sibley College have copies ; but it ought to be possible for every student in any engineering course to obtain one.

A RÉSUMÉ OF LOCAL EVENTS DURING THE FALL TERM, 1893.

The twenty-fifth year of the University's existence was ushered in with exercises befitting the celebration of such an event in the life of a great institution. Cornell was, for a day at the beginning of the term, the hostess of some of America's most noted men, who united with faculty, alumni, and students to do her honor.

The speakers at the commemorative exercises, held in the morning of October 9th, were Dr. Chauncey M. Depew, Hon. Stewart L. Woodford, Rev. Anson J. Upson, Dr. G. C. Caldwell, Mr. J. C. Hendryx, Dr. Theobald Smith, and Professor E. W. Huffcut. In the course of his remarks as orator of the day, Dr. Depew said :

"It is the proud boast of Cornell that she is not only abreast with the times, but is leading them. No traditions retard her growth, and no legends obscure for her the truth. She feels the movement of the intellectual activities of the country and the throbbing pulse of our industrial development. Her twenty-five years are coincident with the unparalleled progress of the United States since the close of the civil war, and her wonderful growth has been stimulated by its impulse. . . . Cornell rounds her first quarter century with a record of growth, maturity, and power unequaled in the history of colleges. Superb as is her youth, it is only the promise of the splendors of her maturity and the ripened and softened grandeur of her age."

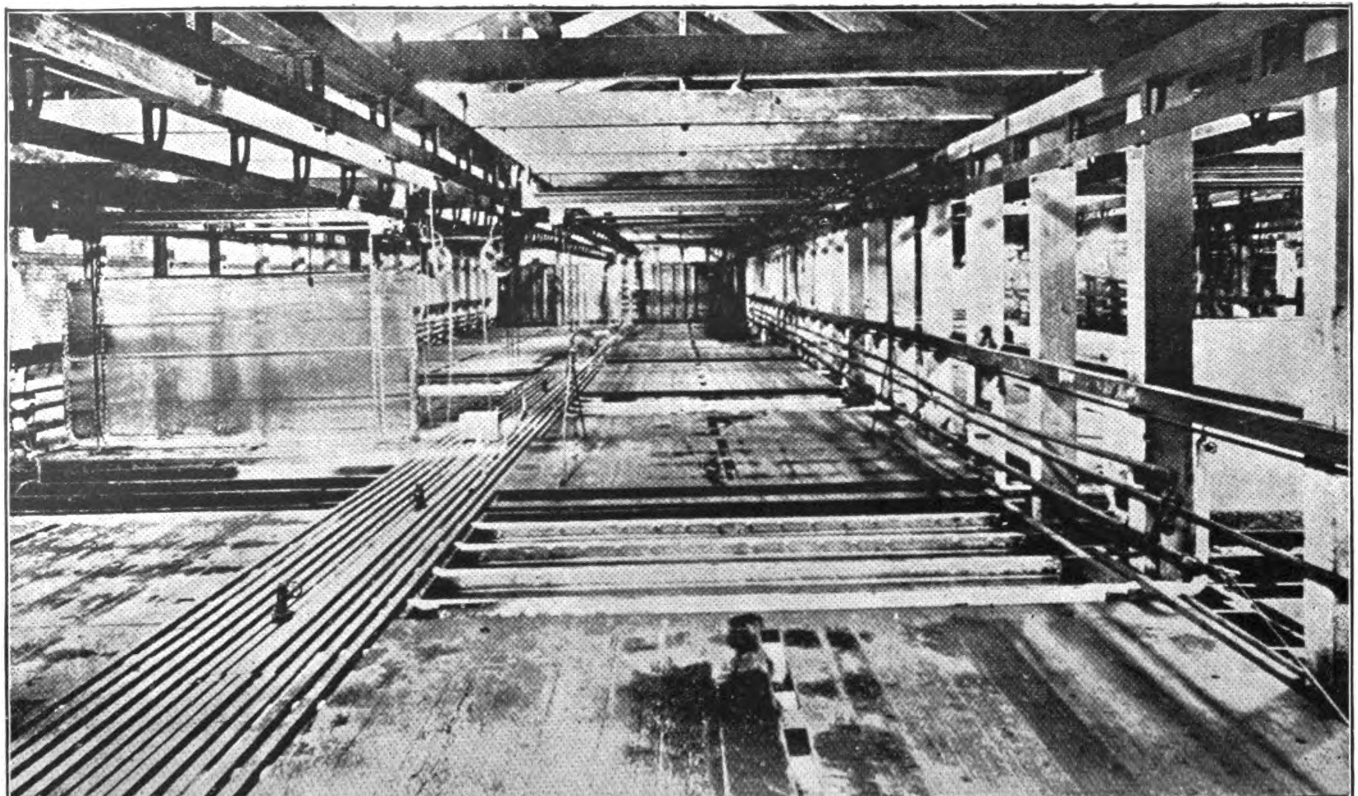
The proceedings of the day were brought to a pleasant conclusion by a banquet in the Armory, at which praise of the name Cornell was the refrain of every speaker.

In coming back to college after the summer's vacation, one looks for changes—changes on the campus, and changes in the faces he sees around him; scarcely a time during these twenty-five years of existence has the builder been idle. One edifice after another had sprung up around the nucleus of 1868, until the Library and Boardman Hall were finally added to the list. Last summer was no exception to the rule of progress, and the 1st of October saw two new structures well under way, the Sibley extension and the Dairy building. The former, which has been occupied but a short time, is almost identical in its exterior appearance to the old wing. The Dairy building, a portion of the future Agricultural Hall, is a handsome little structure admirably adapted to the purposes for which it was built.

As for athletics, the outlook for football was discouraging; we had been shocked during the summer by the news of Witherbee's death and knew that his services as captain and player would be sadly missed; when we learned that Barr had returned to take charge of the team, we were somewhat reassured, but the material he had to work upon was to a large extent inexperienced and this fact, coupled with the usual lack of proper coaching, was the cause of Cornell's unenviable record for the season. Defeats by Harvard, Princeton and Pennsylvania were to be expected, perhaps, but when Lehigh came to our own stamping ground and beat us in such an absurdly easy fashion we—sighed.

During this term very little underclass "spirit" was manifest. The sophomores were victorious in the fall meet by a small margin, but the freshmen won the football games and with them, the right to carry canes.

On November 18 occurred an accident which cast a veil of sorrow over the whole university—the drowning of Dr. Merriam, an instructor in Political Economy, and Miss M. L. Yeargin, a junior in Sage College. Starting for a row when a strong wind was blowing and the water quite rough, they were last seen alive near the light house and heading out into the lake. After weeks of patient search for the bodies, efforts were at last discontinued, but during the Christmas recess Cayuga's treacherous waters gave up one of their victims—the other still sleeps beneath those waves of blue.



VIEW OF COLD STORAGE ROOM.

THE SIBLEY JOURNAL OF ENGINEERING.

VOL. VIII. MAY, 1894. No. 8.

IN CORNELL UNIVERSITY

"The leading object shall be, without excluding other scientific and classical studies, and including military tactics, to teach such branches of learning as are related to Agriculture and the Mechanic Arts, in such manner as the legislatures of the States may respectively prescribe, in order to promote the liberal and practical education of Industrial Classes in the several pursuits and professions in life."—[An act donating public lands to the several States and Territories which may provide Colleges for the benefit of Agriculture and the Mechanic Arts, July 6, 1862.]

MECHANICAL REFRIGERATION—ARTICLE IV.

BY R. C. CARPENTER.

In considering the subject of mechanical refrigeration by compression, the machines made by the Frick Company of Waynesboro, Franklin Co., Pa., should be carefully studied. These machines, while of the same general type as those described in Article II in this series, differ otherwise in nearly every detail.

The general arrangement adopted is shown in Fig. 1, which represents a sectional view of the engine and compressor. As seen from the figure the engine is of the horizontal type, the compressor vertical. The peculiar advantage of this form is due to the fact that the position of the crank and connecting rod is such as to give maximum pressures on the compressor, when required for minimum pressures on the steam piston. The engine generally adopted is of the Eclipse Corliss type, the compressors in each case single acting, but two in number, arranged as as shown in the view, Fig. 1.

In the compressor described in article No. II, oil was automatically pumped into the compressor to fill the clearance space and remove the heat generated during the compression. In this case, however, very different means are provided to accomplish the same purposes.

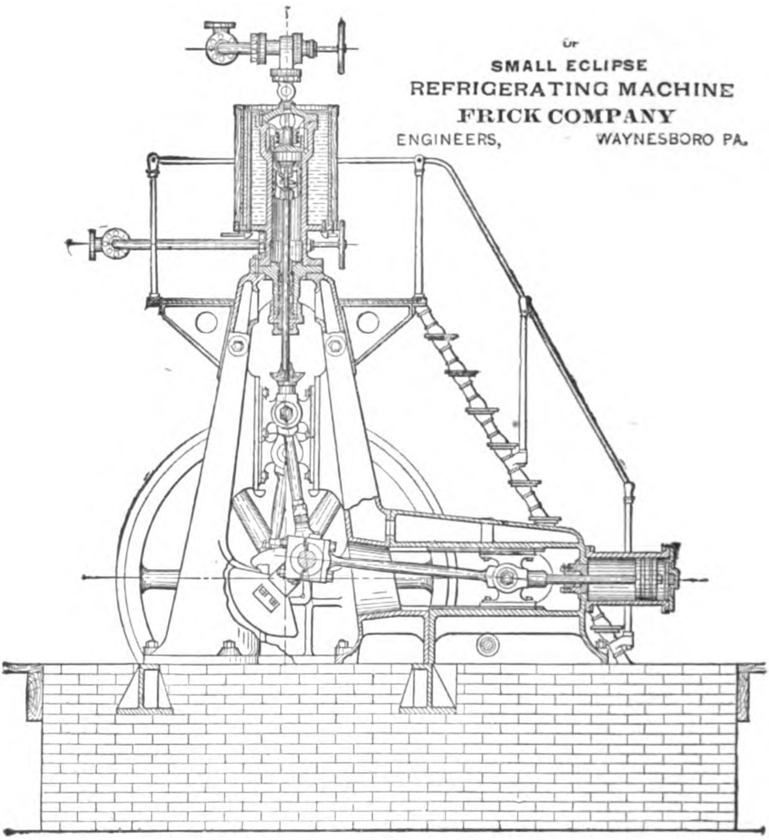


FIG. 1.

Figure 3, shows a sectional view of the Frick gas compressor pump; it will be noticed that it is surrounded with a water jacket, into which the water is fed at the bottom and drawn off at the top. The object of the jacket water is for the purpose of absorbing and removing the heat generated by the compression.

The pump is single acting, but is provided with stuffing box in the lower head and valves in the piston. As the piston falls to the bottom of its stroke, the gas enters and fills the cylinder from the lower end. When the piston rises, the gas is compressed to a pressure sufficient to raise a valve which is in the head and which is seated by a spring, thence it passes through the discharge valve.

In order to expel every portion of the compressed gas, which

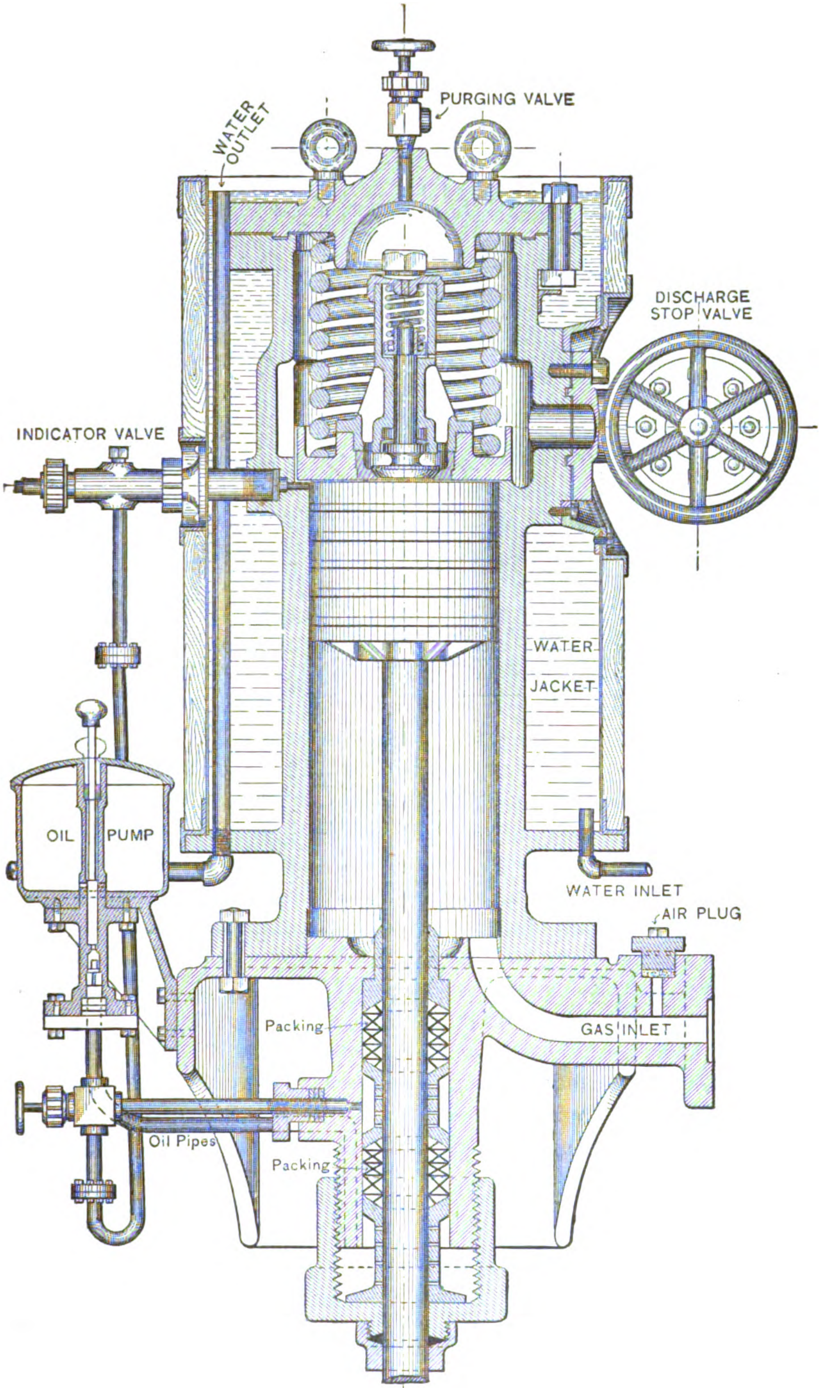

PURGING VALVE
WATER OUTLET
DISCHARGE STOP VALVE
INDICATOR VALVE
WATER
JACKET
OIL
PUMP
WATER INLET
AIR PLUG
Packing
GAS INLET
Oil Pipes
Packing

FIG. 3.

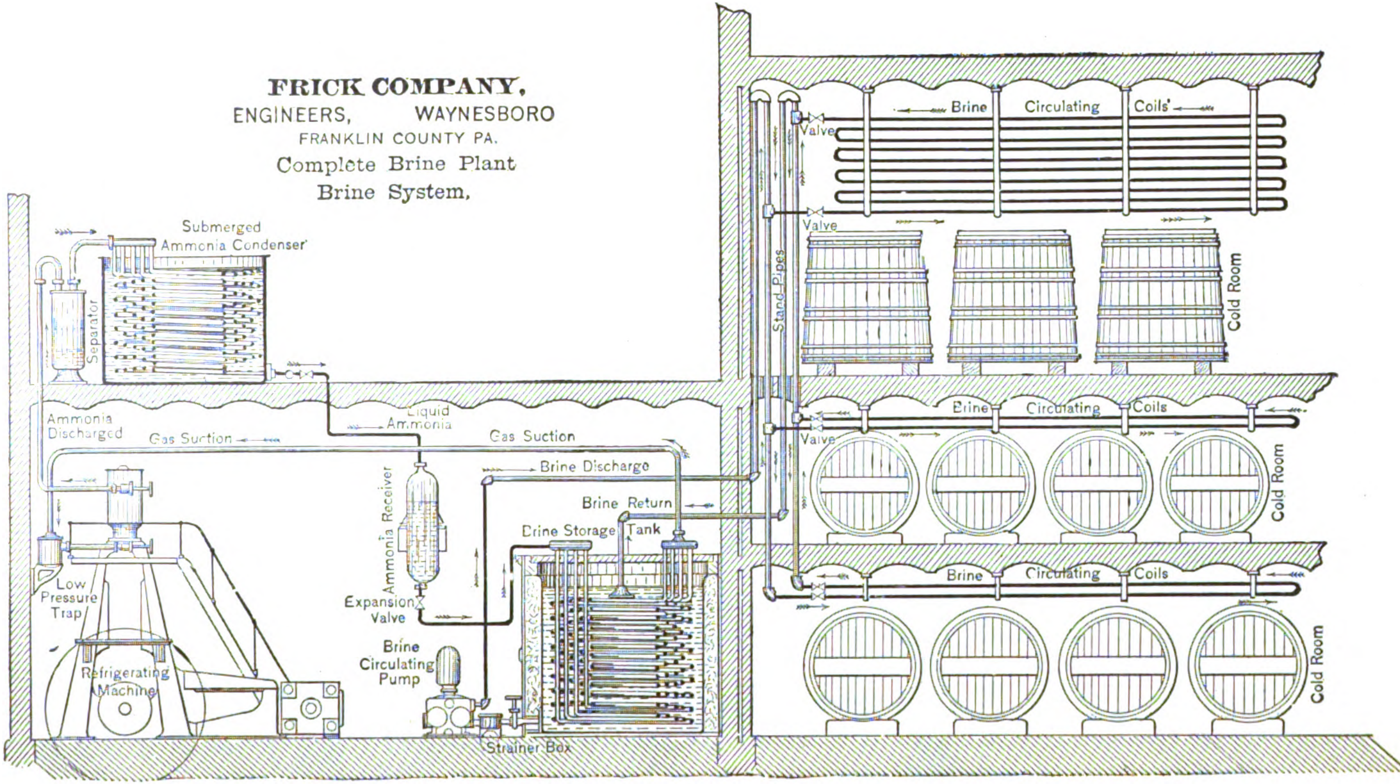

FRICK COMPANY,
ENGINEERS, WAYNESBORO
FRANKLIN COUNTY PA.
Complete Brine Plant
Brine System,
Submerged
Ammonia Condenser
Separator
Ammonia
Discharged
Gas Suction
Liquid
Ammonia
Gas Suction
Brine Discharge
Brine Return
Brine Storage Tank
Ammonia Receiver
Expansion
Valve
Brine
Circulating
Pump
Strainer Box
Low
Pressure
Trap
Refrigerating
Machine
Stand Pipes
Valve
Valve
Valve
Brine Circulating Coils
Brine Circulating Coils
Brine Circulating Coils
Cold Room
Cold Room
Cold Room

FIG. 4.

would otherwise expand and prevent the filling of the cylinder with gas at a low tension, the cylinder head and piston come nearly in contact at the end of the stroke.

To prevent accidents from such close working, the head is held in place by a spring connection, which is very clearly shown in the cut.

In the other machine, the clearances were filled with oil, which had to be removed from the ammonia gas by mechanical separation, requiring both a pump for returning the oil, or its equivalent and a separator. In this system, the clearance is eliminated by the spring head to the cylinder, the extra heat is removed by a water jacket, and the mechanism of the plant correspondingly reduced in amount.

A complete plant of this system is shown in Fig. 4, arranged for cooling brine in a large tank, and then for circulating the cold brine by mechanical means into the rooms to be kept at a low temperature.

A lengthy description is hardly required. The compressed ammonia gas flows to a separator for removing any water, thence to a condenser, where it is cooled and liquified, thence to a receiver, from which it is discharged through an expansion or throttling valve, into coils of pipe having a large volume, and immersed in a tank of brine. This permits the ammonia liquid to expand into gas, the required heat being taken from the brine. The expanded ammonia gas at low pressure is then pumped back in a suction pipe and returned to the compressor, thus completing the cycle. The brine at a low temperature is circulated in the rooms, thus reducing the temperature to that required. In many cases no brine is used, the ammonia being circulated in the rooms where refrigeration is required (see frontispiece) in which case the system is even more simple than that shown in figure 4.

There is a decided difference of opinion regarding the merits of the two classes of compression machines, and so far as the writer can ascertain there is no direct proof bearing on the subject. The machines with large clearances show much higher economy with oil than without, but it is still an open question whether the compression machine using oil gives better results under similar conditions than the best type of the machine just described.

The use of oil, for reducing clearances, is certainly attended with some disadvantages, due to the presence of grease in the refrigerating pipes, in addition to the complexity of the system.

It is also quite certain that there has been a gradual reduction of clearance and of the amount of oil used in the later machines of

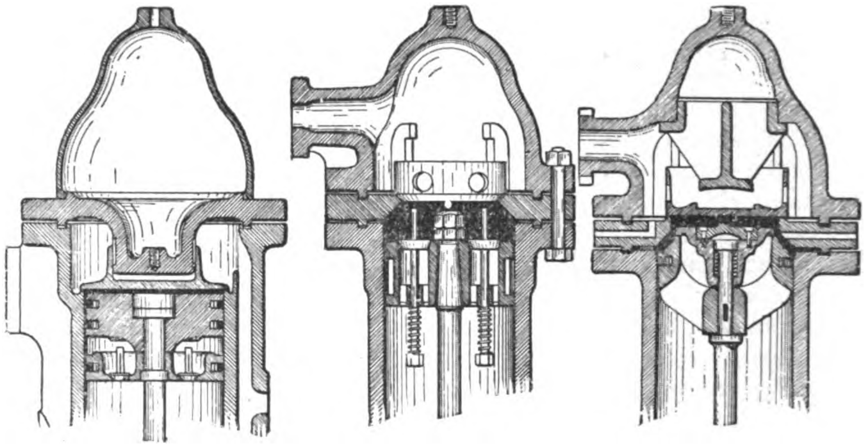


FIG. 5.

the oil type, compared with those built earlier. The cut, Fig. 5, shows by heavy black lines, the changes in the form of piston and amount of clearance and of oil used, in one of the prominent machines of this class for the years 1883, 1887 and 1890.

Fig. 6 shows a sample set of indicator diagrams from the engine and both compressors in the Frick system, which need no especial explanation.

Little more need be said regarding the Frick compressors, a detailed study of the designs as presented show that great attention has been paid to rendering all valves and working parts amply strong and readily accessible. The two pumps are so connected by means of by-pass pipes, that in case it is required to examine the interior of one, all ammonia can be pumped out by the action of the other, thus rendering an accident from that source nearly impossible.

Other types of compression machines differing somewhat from those already described, are built in this country by the Hercules Ice Machine Co., Aurora, Ill., Case Refrigerating Machine Co., Buffalo, Buffalo Refrigerating Co., Buffalo, and Westinghouse Machine Co., Pittsburg. Space will not permit a description.

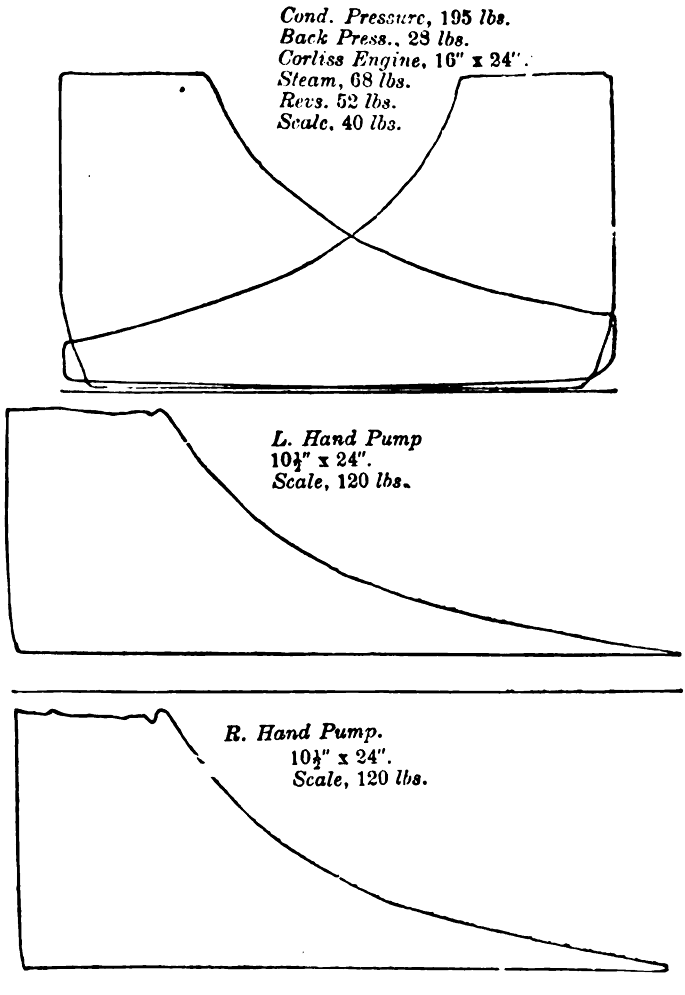
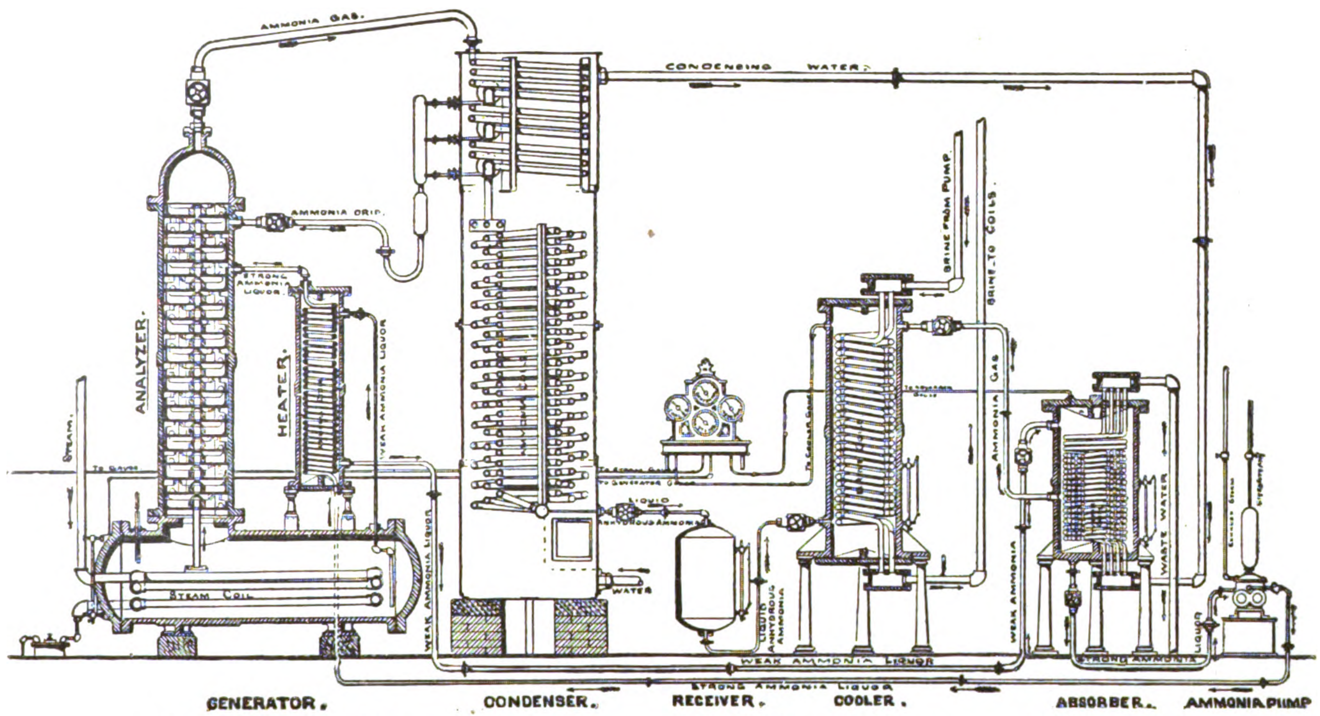


Fig. 6.

THE ABSORPTION SYSTEM OF REFRIGERATION.

This system was invented by M. Carre, and dispenses with the ammonia compressor. Instead of compressing the ammonia by pressure, water strongly impregnated with ammonia gas is heated by steam. The heat vaporizes the ammonia, and because of the low boiling temperature of the ammonia, causes as much pressure as required. The compressed ammonia is treated as in



Sectional View of a leading Absorption System.

FIG. 7.

the other processes, that is, it is first passed through a condenser and liquified, thence to expansion coils, where it takes up heat from the surrounding material. Instead of being pumped back as in the first system, it is absorbed by water and the dilute liquid is pumped.

The cut, Fig. 7, shows a view of an absorption system with all the principal parts named. It is worthy a close study as showing the economy practiced in the use of the heat employed.

Thus the strong ammonia liquid as obtained from the absorber is pumped through a heater, where it is surrounded by weak ammonia liquor which had been previously tested in the generator. Partially heated it then flows to the analyzer, where it exposes a large surface to the heat. The principal part of the ammonia gas, under pressure, passes off above ; the weak ammonia liquor falls to the bottom of the generator. The ammonia gas under the pressure due to its temperature is received in the condensing coil. In this coil the pressure is maintained, but the temperature is lowered by the use of condensing water, so that the ammonia gas is converted into liquid anhydrous ammonia.

The anhydrous ammonia is used as in the other systems ; it may be allowed to expand in a tank filled with brine or it may be carried to the rooms where refrigeration is needed and then permitted to expand. In the figure, the brine system is shown, the expansion taking place in the *cooler*, in which a circulation of brine is maintained by a pump.

The weak ammonia from the *generator*, after parting with some of its heat in the *heater*, is brought in contact with the ammonia in a vesel called the *absorber*. The ammonia gas has a strong affinity for water, and is absorbed readily, converting the weak ammonia liquor into strong ammonia liquor. This is pumped to the heater and completes the cycle. The exhaust steam from the pumps is utilized in heating, under ordinary conditions, so that all the heat wastes are carried off, in the condensing water and in the drip from the *generator*.

This system, while having few moving parts, is complicated by the great number of operations performed by the different vessels, so that in operation it often causes more trouble than the compression system. The exhaust steam from the pumps for circulation of ammonia can not always be utilized, in which case about one-sixth of the total steam is likely to be lost. There are other losses due to water passing over from the analyzer with the gas and to the heat removed from the absorber by the condensing water.

When a low back pressure is wanted, such as is required in production of ice, this system succeeds well and is somewhat more economical than the compression system. For purposes of refrigeration where a high back pressure is maintained the compresssion system is more economical in its operation.

ENGINE TRIALS IN THE MECHANICAL LABORATORY OF THE UNIVERSITY OF LIÉGE.

BY V. DWELSHAUVERS-DERY.

[*Translated by C. P. Matthews, for the Sibley Journal of Engineering.*]

In urging the establishment of mechanical laboratories in technical schools, Hirn recommended that they should be so organized that the students could *obtain useful results while carrying on their studies.* In our *Ecole de Liége*, the courses laid out as preparatory to the examinations for degrees leave to the students but little time in which to make actual trials of engines. A single test includes so many problems that it is hardly possible for each student to make more than one in a year. As a matter of fact, the problems involved reach into almost all the fields of applied mechanics and industrial physics, and present an immense advantage in resting upon data, neither gathered at random nor of pure assumption, but taken during an actual trial. It is the province of the instructor to vary the conditions of the trials made by different groups of students in order that, from a comparison of the results obtained, conclusions of maximum value may be drawn. This method of working has been followed during the past college year at the laboratory at Liége. In addition to two trials made in October, 1893, the object of which was to familiarize the students with the methods to be followed in later studies, arrangements were made for ten trials, by as many groups of students, according to plans which are detailed below.

The engine tested operated at a speed of about 40 revolutions per minute, under a boiler pressure of 55000 kilograms per square metre (78.25 lbs. on the sq. in.), and with a vacuum in the condenser of 690 to 700 mms. (9.8 to 10 lbs. per sq. in). The cylinder was supplied with super heated steam at about 200° C. (392° F.). The maintenance of these conditions depends upon

the skill of the fireman; the following tables show to what extent they were met. *

The first five trials were made with a cut-off at $\frac{1}{10}$th, the last five with $\frac{3}{10}$th cut-off. Compression began 19.3 cm. (0.75 in.) from the end of stroke. Exhaust began 5.4 cm. (2.2 in.) from one end and 7 cm. (2.8 in.) from the other end; the distribution not permitting the same lead on both sides. Of the trials at $\frac{1}{10}$th cut-off, three were made with, and two without steam in the jackets; while of those at $\frac{3}{10}$th cut-off, two were with, and three without steam in the jackets.

Examination of the results of these trials permits a determination of the economy of steam resulting from the use of the steam-jacket; and of the influence of a more or less prolonged expansion.

All the measuring instruments, including indicators, thermometers, manometers, etc., were standardized by the professor in charge and his aids; but, unfortunately, not in the presence of the students. The needed constants of the engine and instruments were calculated and distributed to the students in printed form.

At the beginning of a test each student is furnished with an observation log. His duty consists in filling in the columns with the observations relating to the roll assigned him. When the test is finished each dictates his reading to all the others, so that each man is in possession of a complete log of the test, and can study it independently. There is also given to each observer a set of indicator diagrams. These will, of course, differ slightly one from another.

The water, which, in the form of steam, had passed through the cycle in the cylinder, was diverted by the air-pump of the surface condenser into a vessel placed upon the platform of a balance of the steelyard type, as in Willan's method. The engine was set in operation about on hour before the beginning of the trial. During this period, the water passed from the vessel into a drain. At the instant the signal was made to commence observations, the waste-cock was closed. The task of noting the time and the reading of the revolution-counter was reserved for the professor in charge. The rider of the balance was then set at such a point that the beam would swing when

*The editors regret that lack of space forbids the insertion of the complete data and analysis of these tests. For these, the reader is referred to the *Revue Universelle des Mines*, XXV: 324, 1894.

the vessel contained 100 kilograms, for example. The instant of the rise of the beam was indicated by an electric signal, when the time and reading of the revolution-counter were again taken. To obtain a check, the test was divided into several periods, the rider being placed successively at 200 kilos, 300 kilos, etc. All other observations were made by students, generally at intervals of two minutes. The duration of the trials varied from one to one and one-half hours. Mean values were accordingly obtainable from thirty to forty readings. The students were required to record their readings graphically in order that variations from the mean might be readily detected.

In each trial, observations were made as follows:

(1.) Mercury manometer.

(2.) Metallic manometer and pyrometer in super-heater.

(3.) Water gauge and final temperature of the circulation water of the condenser.

(4.) Initial temperature of the circulation water.

(5.) Automatic purgers of the jackets.

(6.) Temperature in the steam chest, in the jackets, and at the outlet of the air pump.

(7.) Revolution counter.

(8.) Condition of the brake.

(9–11.) Indicator diagrams.

In a simple commercial trial it would not be necessary to go into detail; because the gain from the use of the steam-jacket is evident. In the trials at $\frac{1}{10}$th cut-off, without jackets, the mean consumption is 12,101 kilograms per *Cheval-heure* (26,68 lbs. per H. P.—hour), and with jacket 9.618 kilos. (21.2 lbs); showing a gain of 20 5 per cent. At $\frac{3}{10}$th cut-off, the mean consumption without jackets is 11.515 kilos. (25.39 lbs). and with jackets 9.988 kilos. (22.02 lbs.), or an economy of 13.3 per cent. *Without jackets*, cut-off at $\frac{3}{10}$th causes a gain of 4.84 per cent. over that at $\frac{1}{10}$th; *with* jackets, a cut-off at $\frac{3}{10}$th is accompanied by a loss of 3.7 per cent.

The economy due to the jacket resides, as Hirn has shown, in its influence upon the thermal actions in the metallic walls of the cylinder. During admission, live steam rushing against the cold metal is partially condensed and gives up to the walls an amount of heat equal to R_a. The principal effect of the steam-jacket is to diminish the initial condensation, or the value of R_a., during admission. Thus these trials show an initial condensation with $\frac{1}{10}$th cut-off of 42 per cent. *without* jacket, and 23 per cent *with*

jacket; and with $\frac{3}{10}$th cut-off 28 per cent *without* jacket and 13 per cent. *with* jacket. Consequently, the value of R_s is of prime importance. It is influenced by the temperature at which metal is held, which is 30° higher when the jackets are in operation than when they are idle, and also by the extent of metallic surface exposed, and by the speed. For this reason, it is important to ascertain, in addition to the value of R_s, the number of heat units exchanged per unit area of surface, and per hour, as well as the weight of steam condensed per unit area and per hour.

Conclusions.—Steam-jacketing in this engine, gives greater economy at $\frac{1}{10}$th cut-off than at $\frac{3}{10}$th. Short cut offs are not economical without the use of the jacket. Thus, from $\frac{1}{10}$th to $\frac{3}{10}$th, there is a gain of 4.84 per cent. while *with* jackets this result is reversed, and there is a gain of 3 7 per cent. in diminishing the cut-off from $\frac{3}{10}$th to $\frac{1}{10}$th.

It will be necessary to continue these trials with varying degrees of expansion in order to verify the law which the author has enumerated, viz, *Maximum efficiency is obtained when the metal is dry at the beginning of exhaust.*[1]

[1]. "La marche la plus économique d'une machine à vapeur est obtenue lorsque, par un procédé quelconque, on est parvenu à faire en sorte que le métal des parois du cylindre soit absolument sec sur sa face interne dès le commencement de l'émission ; en d'autres termes, que la vapeur evoluante soit, au commencement de l'esmission exactement sèche ou légerèment surchauffée, qu'aucune partie n'en soit répaudue en rosée sur le métal."—*Étude expérimentale Calorimétrique de la Machine à Vapuer.* par V. Dwelshauvers-Dery. Page 75.

See also Thurston's MANUAL OF THE STEAM ENGINE, Vol 1, p 648 *et seq.*

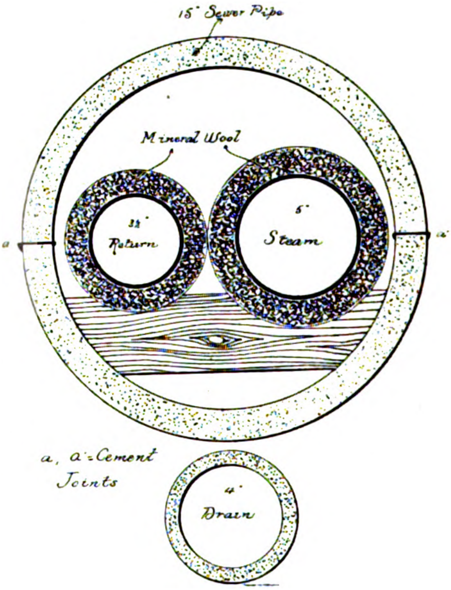
PROTECTING UNDERGROUND STEAM PIPES.

BY G. W. BISSELL, AMES, IOWA.

For the purpose of carrying steam from a battery of boilers to one of the buildings of the Iowa Agricultural College it was necessary to put the pipe underground for a distance of two hundred feet. The construction adopted is described as follows :

Both the steam and the return pipes were laid in the same trench and were laid with a grade of five-eighths of an inch in ten feet and drained towards the boilers. The steam pipe was five and the return pipe three and one-half inches in diameter.

The trench was dug to grade. It was about twenty inches wide at the bottom and not much more at the top, the soil being clay and the season dry. The depth varied from four and one-half to nine feet. Below the grade of the trench was laid a line of four-inch drain tile which was connected with the drainage system of the college grounds.



The outside covering or conduit for the pipes was constructed of fifteen-inch vitrified sewer tiles laid with joints of best Portland cement. To facilitate the laying the sewer tiles were halved lengthwise by means of a set hammer. It was cheaper to split the tiles than to buy half tiles from the tile works, the cost of whole and half tiles being the same per foot. The corresponding halves were marked for identification and were called uppers and lowers. The lowers were first laid and their joints made with Portland cement. In laying the lowers the proper grade was obtained by a long straight-edge and level and verified by the Y-level and rod. At intervals of six feet wooden chairs were placed. These were sawed from two-inch plank to fit the inside of the tiles and the outsides of the covering of the steam and return pipes, and were dipped in asphaltum paint. The steam and the return pipes were laid upon these chairs, two or three lengths

being screwed together at one end for a start. This first section of each pipe was raised from the chairs, first at one end and then at the other, to allow of the placing of the non-conducting covering. Then two more lengths of each pipe were added to the line and the covering applied by raising the advancing end to clear the chairs by the necessary amount, and so on until the whole line was laid and covered. The uppers were then placed and all joints made in Portland cement. Back-filling completed the job. Expansion was provided for by ample offsets at the ends of the line. The non-conducting covering used on the pipes was mineral wool sectional covering: the sections were joined with pasted strips of heavy paper and cloth.

The drawing herewith shows the construction in cross-section. The total cost of the job was four hundred seven dollars or a little over two dollars per foot.

The job was done last fall and the pipes were in service until November 15. This spring they were put into service February 15 and have been in use ever since. Thus far the insulation has proven very effective. At no time have there been visible effects, such as melting of snow on the ground above, of defective insulation.

MANNESMANN PROCESS FOR MAKING SEAMLESS TUBES.

BY HENRY F. SCHOENBORN, JR., '95.

Prior to the year 1885, the manufacture of metallic tubes consisted in rolling the glowing metal into sheets and riveting or welding the latter. To give them special strength they were sometimes galvanized.

About the year 1887, the Mannesmann brothers of Germany invented a process of producing seamless metallic tubes. In their process they use a machine in which two rollers, so placed that their axes have certain definite positions relative to each other and are not parallel, revolve in the same direction. The theory of the machine is based upon the fact that, by arranging the rolls in certain positions and at certain angles, they will develop a tubular formation in a solid metallic ingot placed in a position for their action. By placing them in this position a rupturing of the metal along the vertical axis is caused by the revolution of

the rolls, which rupturing displaces the material radially from the centre. By this means the solid blank is transformed into a seamless tube without the use of a mandrel. Although, as has been said, no mandrel is *necessary*, still, for the reason that the inside of the tube so formed is rough and unfinished, it is customary to remedy this defect by forcing a pointed mandrel through the tube.

Generally the blanks which are to be made into tubes are at a welding heat, but with the softer metals, such as lead or brass, the material is at the ordinary temperature.

Fig. I

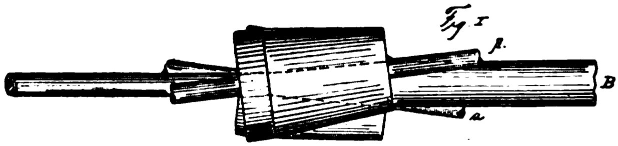


Fig. II

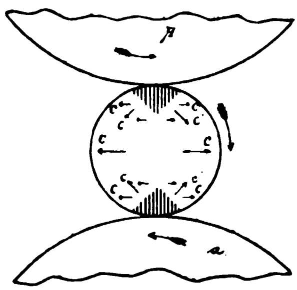
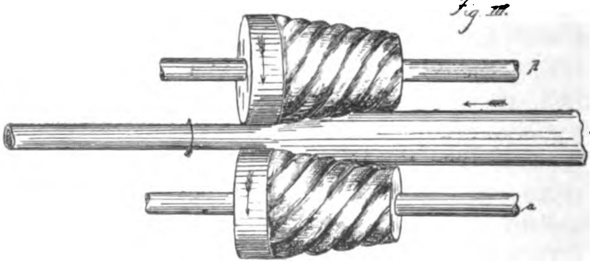


Fig. III



The shape of the rolls and the relative positions of their axes are modified to meet the conditions necessary to produce the results desired in each case. As may be seen by reference to the accompanying figures, the axes of the rolls lie in parallel vertical planes but at angles to the horizontal, and these angles are in opposite directions; in other words, the axes dip in opposite directions. When only two rolls are used suitable guides

must be provided for properly supporting and guiding the blanks.

After the tube has been started by the action of the rolls it is made to run upon the end of a pointed mandrel, the diameter of which determines the inside diameter of the tube. The exterior diameter of the tube is determined by the width of the narrowest part of the space between the working faces of the rolls. The mandrel is made in the form of a movable head, which is seated in the end of a long rod of smaller diameter than the inside of the tube. The mandrel if desired may be made hollow and may be kept cool by the circulation of water through its interior, and it can be removed, and replaced by larger or smaller ones.

Sometimes the rolls have their working faces provided with spiral corrugations. This gives them a more effective hold upon the metal of the blank, and thus causes the displaced metal to flow more nearly in the direction in which the rolls act. This uneven surface of the rolls is decidedly advantageous, because it twists the fibers of the metal to a considerable extent. The working surfaces of the rolls converge sufficiently to offer enough resistance to the passage of the blank of metal so that it will not slip through too easily.

The stresses induced in the metal by the action of the rolls may be seen in Fig. 2. Variation in the adjustment of the rolls determines the amount of reduction in the external diameter of the blank and also determines the size of the hole produced. After repeated experiments it has been found that in pipes made by this process the tensile strength of the metal is greatly increased, the result being similar to that produced in wire-drawing. Tubes made by this process are more than twice as strong as the lap-welded tubes; and some tubes have stood a pressure of four tons per square inch. It has also been found that an inferior metal—one not perfectly homegenous in its composition and quality—will not stand the test of being run through the rolls, and that it is impossible to make a tube of such material.

The pipes are made, in the usual lengths, 18 to 23 feet long, but they are also being made in lengths of 45 feet.

The application of the Mannesmann materials are very numerous, especially in the construction of bridges and roofs. Bridge builders who found it difficult to obtain materials which were light enough and at the same time had the necessary strength, found this material specially adapted for that purpose. The Mannesmann brothers are now manufacturing these tubes at Kotoman in Bohemia, Remscheid in Germany, and also at London.

AN ANALYTICAL STUDY OF THE INITIAL CONDENSATION IN STEAM ENGINES.*

BY LIONEL S. MARKS, B.SC.

The steam engine of to-day is a machine of considerable economy relatively to that of a generation ago, but when compared with the proper absolute standard it is seen to afford room for considerable improvement. This improvement can chiefly be effected by decreasing either one or both of the two great sources of loss of economy in the steam engine,—the thermodynamic wastes and the internal wastes. The laws governing the thermodynamic wastes are well known, thanks to the labors of Clausius and Rankine, and the methods of reducing them, so far as is practicable or financially desirable, are very generally carried out. The same, however, cannot be said of the internal wastes. These wastes have been the subject of investigation by engineers from the time of James Watt to the present day, and will afford a rich field for experimental work for many years to come.

The writer proposes in the present article to analyze the results of the experimental work which has been carried out with the purpose of determining the laws governing the internal wastes; to see what conclusion can be drawn from such work; and to indicate the lines along which further investigation is necessary.

It will be well to glance rapidly over what is now known on the subject. The internal wastes may be considered as being wholly due to cylinder condensation, for the loss due to the heating of the clearance steam is very small. It is probable that the generally received opinions of the manner of action of the cylinder walls; of the rapid condensation during admission; of the coexistent condensation and re-evaporation during expansion, the former being in excess for a short time at the beginning, and the latter for the remainder of expansion; of the sudden, and probably, total, re-evaporation during exhaust; are substantially correct in the light of what is now known. The phenomena of cylinder condensation are, of course, known to be due to the difference in temperature between the internal surface of the walls of the cylinder and the steam in contact with it, and the causes governing the magnitude of the action have been ascertained in a general way. Thus, it is known that the weight of steam con-

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* Abstract of thesis presented for the degree of M.M.E.

densed by the walls is some function of the range of temperature of the cylinder walls, of the surface exposed to the steam, of the speed of revolution, and probably of several other factors. Beyond this there is but little on which authorities on cylinder condensation are agreed.

Several investigators, finding from the results of experimental work that condensation varies as certain constant functions of the time of revolution, range of temperature, etc., have multiplied all these functions together, and thus have obtained formulae for condensation. The formulae derived from different sets of experiments do not, however, agree with one another. Thus, some investigators find the cylinder condensation to be inversely proportional to the square root of the number of revolutions per minute, others to the two-third power of that quantity, and yet others to the first power. Similarly some authorities maintain that the loss to the walls is proportional to the total range of temperature of the steam, others to its range during expansion, while others see no apparent relation between cylinder condensation and any range of temperature of the steam. These apparently conflicting facts can be accounted for quite simply on the hypothesis, that the law of variation of cylinder condensation with any one variable under any set of conditions is not of necessity true where these conditions are altered. Thus, the law of variation of cylinder condensation with engine speed for any particular engine, running under fixed conditions of ratio of expansion, initial pressure, etc., need not be, and in fact is not, the same as when the ratio of expansion, or initial pressure is different. It follows then that the experimental fact mentioned above, that in different experiments cylinder condensation has been found to be inversely proportional to the square root, to the two-third power, and to the first power respectively, of the speed of revolution, is explainable by the fact that the engines and the conditions of their working were different in the different experiments. Also, it is evident that the quantity to which the cylinder condensation is proportional when any condition is varied is not a constant function of that variable, but is a function containing functions of all the other variables. The determination of the laws governing cylinder condensation is then a problem of much greater complexity than has hitherto been supposed.

Investigations, to be of value, must, above all else, be systematic and arranged on a definite plan, varying one condition only during a series of runs. A very satisfactory plan is that which

was adopted in the experiments, mentioned later, by Mr. Barraclough and the writer. In these a series of speed trials was made under fixed conditions of initial pressure, ratio of expansion, and back pressure. They were then repeated several times with other initial pressures, all conditions except speed being kept constant throughout each series of runs. The whole of these trials should be repeated for a number of different ratios of expansion, and so on with all the variables. Such an investigation as this, if completed, would determine the method in which, the law connecting the variation of cylinder condensation with any variable, varies when the conditions under which the engine is running are altered.

The best absolute measure of cylinder condensation is the number of heat units given to the cylinder walls from the beginning of compression to the end of admission. Most of the proposed formulae for cylinder condensation by the different investigators give instead of this the percentage of the steam admitted that is condensed up to the cut-off; but as this quantity depends on the indicated water rate, this latter should appear in the formula. Since it does not, the formulae must be inaccurate except for one particular indicated water rate. Similarly those formulae which give the total weight of steam condensed should

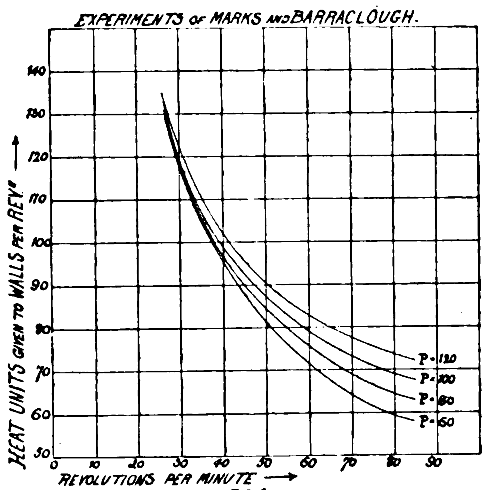


FIG. 1

contain as a factor the latent heat of the steam. By adopting the heat loss as a measure of the condensation the formula will be simplified and will be more rational. It is generally difficult to

ascertain with any precision the heat loss during compression, and as this loss is generally very small it has been neglected in most of the experiments referred to later. In high speed engines, however, where the compression is large, this heat loss cannot be neglected.

The speed of revolution of an engine is one of the most potent factors in determining the magnitude of the initial condensation in the cylinder. If the temperature cycle of the walls is maintained constant during a series of runs at different speeds, it can be demonstrated from Fourier's theorem, that the condensation varies inversely as the square root of the speed. But all that can be done with a steam engine is to keep the initial and back pressures and the rates of expansion constant. This, however, does not insure a constant temperature cycle of the walls; it does not even insure a constant temperature cycle of the steam. Hence it is found that the condensation does not follow the inverse square root law. Nearly all the experimental work, however, appears to show that the condensation varies inversely as some power of the speed, and the writer has consequently assumed the exponential equation

$$H = \frac{C}{N^x}$$

to represent the relation between the cylinder condensation H and the speed of revolution N for an engine running under any set of conditions, where the constant C and the exponent x assume different values for different sets of conditions. It is possible that some other form of equation might equally well fit the experimental data, but as this is certainly the simplest form and is that of the theoretical law, it has been adopted here.

In Table I, are given the values of the exponent x for all the reliable speed trials that the writer has been able to find, and the type of engine and the conditions under which it was working are also stated there. The method of finding x may be of some interest. The equation

$$H = \frac{C}{N^x}$$

can be written in the form

$$\log H = A - x \log N$$

from which we get

$$\frac{d \log H}{d \log N} = -x.$$

Hence if the values of H obtained from any series of experiments be plotted on a logarithmic scale, against the corresponding values of N also plotted on a logarithmic base, the curve drawn through the points will be a straight line if the exponential law is true, and the tangent of its inclination will be the value of the exponent x. Fig. 2 contains the curves for the writer's experiments plotted in this way; plotted on the ordinary scale they appear as in Fig. 1. All the trials recorded in Table 1, were plotted in this way and in no case did the curve drawn differ markedly from a straight line.

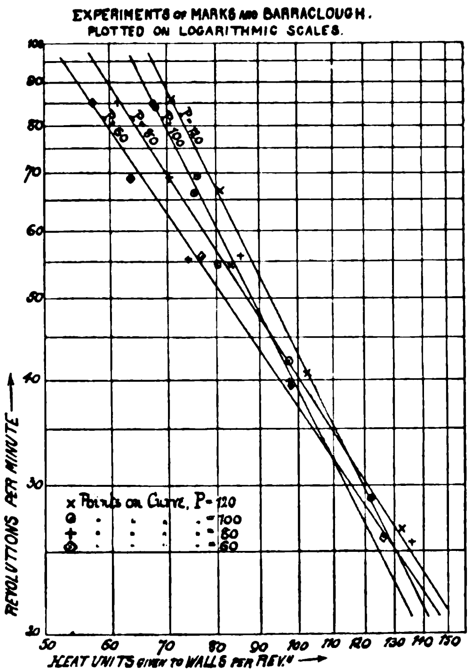


Fig. 2

Glancing through the table it will be seen that the exponent x varies from .4 to 1.4. This variation we have seen is probably the result of the different conditions under which the trials were made. The conditions likely to affect the law of variation are range of temperature in the cylinder, ratio of expansion and initial pressure.

TABLE 1.—SPEED TRIALS.

Reference Number	Names of Investigators.	Kind of Engine Tested.	Size of Engine. . .	Point of Cut-Off. .	Initial Pressure. Absolute.	Value of x in Equation $H \times N^x =$ Const.
1	Marks and Barraclough.	Simple Corliss.	9″×36″	.32	120	.49
2					100	.50
3					80	.64
4					60	.68
5	P. W. Willans.	Simple Non-Condensing.	14″×6″	.437	50	.61
6				.339	70	.66
7				.264	90	.67
8				.216	108	.67
12		Compound Condensing H.P. Cyl.	8.5″×6″	.58	125	.4
13					83	.54
14					60	.82
15					37	.97
16		Compound Condensing L.P. Cyl.	14″×6″	.28	140	.5
17					160	.57
18				.45	38	1.1
19					22	1.4
20	Denton and Jacobus.	Simple.	17″×30″	.599	106	.66
21				.313		.54
22				.182		.59
24	Emery.	Simple Condensing	8.25″×8″	.23	95	.7
26	Delafond.	Simple Condensing	22″×44″	.5	62	.9
28	Escher.	Non-Condensing			47.0	.64
29					60.4	.55
30					73.5	.55
31		Condensing			47.0	.68
32					60.4	.59
33					73.5	.56
34	English.	Non-Condensing			60	1.1
35					48	.95
36					37	1.1
37					28	1.25

A review of the non-condensing tests 28, 29, 30, and the otherwise similar condensing tests 31, 32, 33, by Escher, show that the exponent x is but little altered by increasing the range of temperature of

the steam. Since the alteration is slight and the data are insufficient to determine it exactly, the effect of range of temperature will be neglected. The manner in which the ratio of expansion alters the value of the exponent is seen by the three series of experiments 20, 21, 22, by Denton and Jacobus. These cover the range of expansions commonly in use and show that the ratio of expansion used is of some importance in determining the law connecting cylinder condensation and engine speed. Here again, however, the effect can only be seen in a general way, owing to lack of sufficient data, and in view of the fact that it is of relatively small importance compared with that of the last factor to be considered, it will be neglected. This last factor is the initial

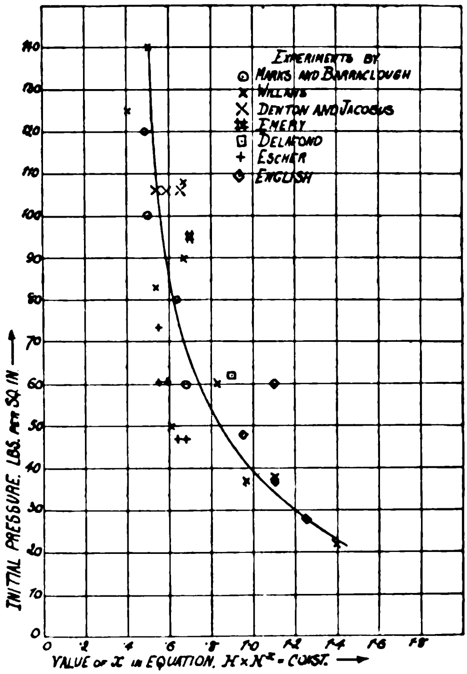


FIG. 3.

pressure. In Fig. 3 points have been drawn coördinating the value of the exponent x with the initial pressure for all the series of trials recorded in Table 1. A curve drawn through these points would show exactly how the initial pressure in an engine affected the law connecting the initial condensation and the engine speed, if the trials plotted had all been for the same engine with a con-

stant ratio of expansion and back pressure. The curve actually drawn in Fig. 3 represents the plotted points with very fair accuracy, and may be taken as demonstrating that the type and size of engine, the ratio of expansion, and the back pressure, have at most but slight effect in altering the law connecting initial condensation and engine speed. The points most distant from the curve, are for the tests by Escher and English, which were only made on the clearance space of an engine or its equivalent, and when these are rejected, and the possible inaccuracy of engine tests is considered, the above conclusion is further reinforced. It may then be laid down that the factor of greatest practical importance in determining the law connecting cylinder condensation and engine speed is the initial pressure of the steam used, and that the other working conditions are of relatively small importance. The curve drawn is represented very accurately by the formula.

$$x = \frac{27}{P} + \cdot 3$$

where P is the absolute initial pressure of the steam. Hence finally the relation between the initial condensation occurring in a steam engine and the speed at which it is running, is approximately expressed, for any set of conditions, by the equation

$$H \times N^{\left(\frac{27}{P} + \cdot 3\right)} = C.$$

It may be pointed out that the theoretical square root law is true for an initial pressure of 135, and that condensation is inversely proportional to speed at about 40 lbs pressure.

The next point to be considered is, what effects have the density of the entering steam and the range of temperature of the steam in the cylinder on the initial condensation. Considering the former factor first, one would expect on theoretical grounds that the density of the steam would have but slight effect, since the surface of the cylinder wall probably attains almost immediately, at admission, the temperature of the steam, so that the heat absorbed by the wall depends almost entirely on its conductivity and the gradient of temperature within it. During the other periods in the stroke also, the density of the steam can only modify the heat exchanges very slightly. The experimental evidence on this point is conflicting and more work needs to be done on it.

The effect of range of temperature in the cylinder has been worked out more fully. If the increased range of temperature is

obtained by lowering the back pressure, the heat given up by the walls to evaporate the water present at release, will be less for the greater range of temperature. At the same time the heat given up by the walls during exhaust, when they have become dry, will be increased. If the decrease in the quantity of heat given up to evaporate the water present at release, when the back pressure is reduced, were equal to the increase in the loss from the dry walls, the total heat rejected, and consequently received, by the walls per revolution would remain constant, whatever the back pressure. The experimental data of Escher, English and Delaford show this to be the case. It thus appears that the heat given up by the cylinder walls may be taken as consisting of two parts, of which one, given up during expansion, is probably a function of the range of temperature during that period, and the other, given up during exhaust, is really independent of the fall of temperature from release to back pressure. The common assumptions that initial condensation is proportional to the total range of temperature in the cylinder, or to the range during expansion, have no apparent foundation in fact, as far as can be ascertained from experiment.

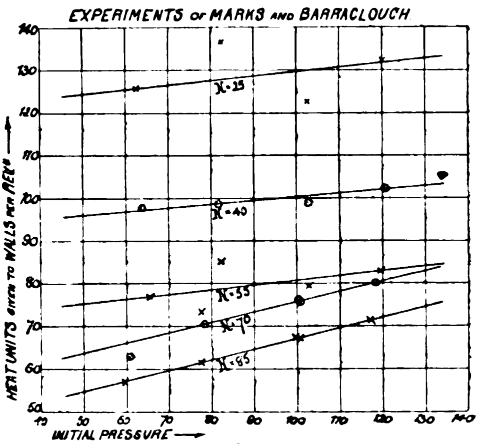


Fig 4.

The greater part of the experimental work dealing with the effects of variation of initial density or range of temperature consists of trials in which the initial pressure is altered and the back pressure is constant, and contains both these qualities as variables, and as this is the practical case, it will be well to see the sum of the two actions. In Fig. 4 are plotted the results of the

writer's experiments on this subject and they show a constant rate of increase of initial condensation with increase of initial pressure. Willans' experiments and practically all the others that are available, show the same thing. Hence the condensation can be expressed by

$$H = aP + b$$

where P is the initial pressure, and a and b are constants depending on the conditions under which the engine is running. The experiments of the writer and of Willans show that the higher the speed of the engine, the less is the value of b and the greater that of a The constant a appears to be nearly proportional to the speed of the engine. The constants also vary with the size of the engine, and with the ratio of expansion, but the experimental data available are not extensive enough to permit of the determination of the manner of this variation.

Finally, the effect of the ratio of expansion upon the initial condensation will be glanced at. The ratio of expansion is not a physical quantity and so cannot logically be supposed to enter into the problem of cylinder condensation. It affects, however, several physical quantities, the extent of surface exposed to admission steam, the durations of admission and expansion, the

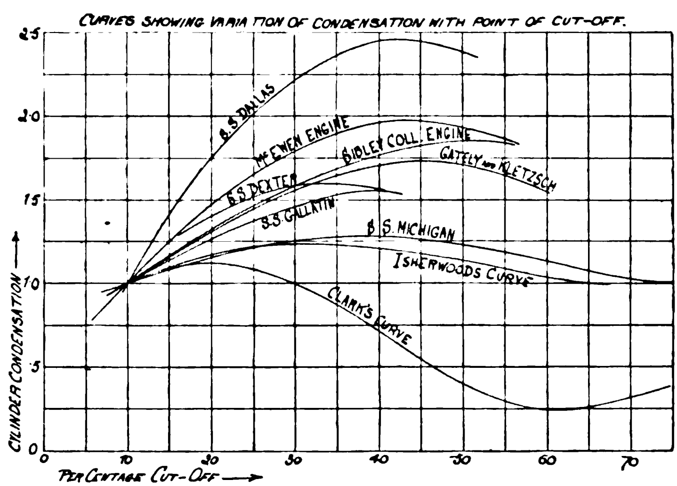


Fig. 5.

range of temperature during expansion, etc., and it is the sum of the actions of all these physical factors which is here to be considered. The logical method would be to consider each of these actions separately, but the experimental difficulties in the way of so

doing are very great, if not, indeed, insurmountable. The effect of the extent of surface exposed might be ascertained by increasing the clearance surface while maintaining its volume constant, but the effects of varying the other conditions probably cannot be ascertained singly.

In Fig. 5 are plotted curves showing the manner of variation of cylinder condensation with the point of cut-off for a large number of engines. If the law of variation were constant, all these curves would be similar, and if they all passed through one point they would coincide altogether. Accordingly in each engine the condensation at 10% cut-off has been taken as the unit of condensation so that all the curves pass through the point whose ordinates are 10% cut-off, and unity of condensation. The fact that the curves do not coincide shows that the law of variation of initial condensation with point of cut-off depends upon the proportions of the engine and upon the condition under which it is running. The data at hand are insufficient to show how these conditions modify the law under consideration.

It will be observed that all the curves given pass through a maximum value, and those which are continued far enough show an inversion of curvature and pass through a minimum value. The results of many other experiments also, which are not shown in the figure because they do not include experiments at a cut-off early enough to permit of the determination of the assumed unit for condensation, show the same inversion in curvature and passage through a minimum at a late cut-off. The general deductions which can be drawn from these curves are that the initial condensation occurring in a steam engine cylinder attains a maximum at a cut-off of about 40 per cent.; that it is practically constant throughout the ordinary range of cuts-off, say from 20 to 60 per cent.; and that it passes through a minimum value at about 80 per cent. cut off.

Besides the conditions already mentioned as affecting cylinder condensation, there are several others such as type, proportions and dimensions of engine, etc., on which, however, no special experimental work has been done. When the effects of the variations of each of the factors which help in determining the magnitude of the initial condensation in a steam engine cylinder shall have been found out, it will be possible to determine the ultimate constant, the amount of heat given per revolution to unit area of the surface of an engine working under some assumed standard conditions. When this has been done the experimental theory of the steam engine will be completed.

THE BEHAVIOR OF SINGLE-PHASE SYNCHRONOUS MOTORS.

BY HARRIS J. RYAN.

It is generally understood that alternate current generators operate equally well as synchronous motors. This is true of some alternators but not of all. The old smooth bodied armature alternator with "pan cake" armature coils made a very poor synchronous motor, while the modern alternator with "T-toothed" armatures fitted with machine wound armature coils has been giving excellent results when run as a synchronous motor. This improved performance of the alternator as a synchronous motor is due to the useful effects of the armature currents on its own field. When the current developed by a generator is in unison with the generated E.M.F., such current exerts very little effect upon the field—neither strengthening nor weakening it. When the current lags behind the E M.F. of the generator the armature reaction effect that it produces upon the field is such as to weaken the field, and thus to diminish the E.M.F. produced by the generator. The reverse of this action occurs when the generator furnishes a current that is in advance of its E.M.F. Precisely the same armature reactive effects on the field occur in a synchronous motor. There is this exception, however, that the motor E.M.F. is counter to that of the generator, so that what is a lagging current for the generator is an advance current for the motor, and the current that is in advance of the generator E.M.F. lags behind the counter E M.F. generated by the motor. The current that strengthens the field of the generator will weaken the field of the motor, and the inverse relation is likewise true.

The speed depends only on the periodicity produced by the generator and the number of poles of the motor, as is well understood. No variation of the E.M.F. impressed at the terminals of a synchronous motor nor variation of its field excitation will change the resulting speed so long as the motor operates at all. The armature currents of the motor, generator, and line always possess some self induction. When, therefore, the generator pressure is higher than that of the motor at the moment synchronism is obtained, and the machines are connected together, a

current will pass between the machines that will lag, because of the self-induction, behind the generator E.M.F., and will be in advance of that of the motor pressure. This current, as was just pointed out above, will weaken the field of the generator and lower the E.M.F. that it generates; it will strengthen the field of the motor, and in proportion will raise its counter E.M.F. The result, therefore, is to equalize the developed pressures of generator and motor, and thus prevent a further increase of current. Such a current will have a larger component in unison with the generator pressure than with that of the motor, and the differences will be proportional to the electrical energy transformed into mechanical energy.

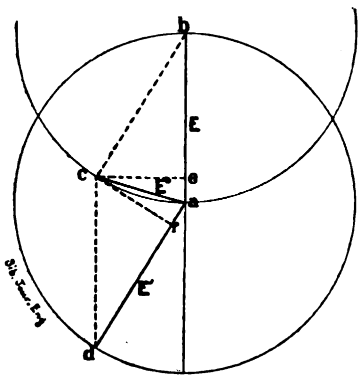


FIG. 1.

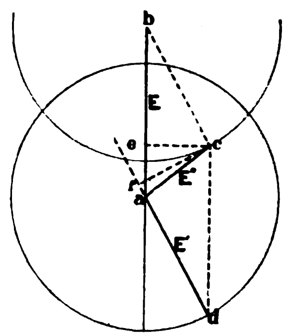


FIG. 2.

In Fig. 1. is a diagram that illustrates the action of a synchronous motor that develops a motor pressure E' equal to the generator pressure E. The circuits are assumed to have no self-induction, but the usual resistance. At the instant synchronism is obtained and the connection of the motor completed, there can be no current established through the motor, and therefore, no power developed. The motor will lag in rotative speed at once to some such position as *d*, where the resultant of the motor and generator pressures is *ac* or E''. There is no self-induction in the circuit and the resulting current is in unison with E''. Such a current has component values in unison with the generator and motor pressures that are equal. No power can, therefore, be developed and the motor would promptly come to a standstill.

The conditions represented by Fig. 2. are that the generator pressure is greater than the motor pressure and that the circuits possess resistance but no self-induction. At the moment the

motor is synchronized and connected, a current will be established that is in unison with the generator pressure and opposite to that developed by the motor. The developed power that thus results is in general more than sufficient to keep the motor running light at synchronism. The speed position of the armature is, therefore, advanced to a point *d*. Here is obtained a resultant E.M.F., E'', that, since there is no self-induction, establishes a current which is in unison with itself, and has a diminished component value along E. A balance occurs at that point where the power developed is just sufficient to keep up the synchronous speed of the motor armature, and no further acceleration takes place. On loading down the motor its armature position is retarded. The maximum load that the motor will stand is that at which the product of the motor pressure into the component of the current that is in unison with it is a maximum. This the diagram plainly indicates to be at the point of true synchronism. When this point is reached an increase in the load will further retard the armature, and the above product will again diminish ; the motor, being overloaded, will come quickly to rest.

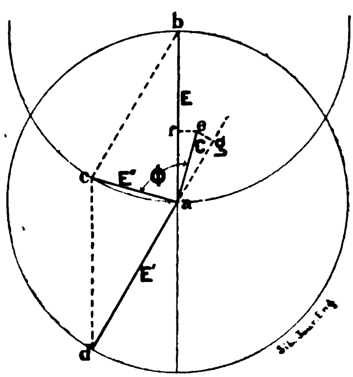


FIG. 3.

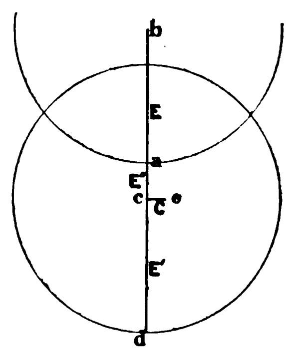
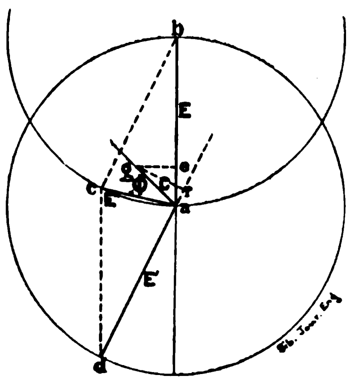


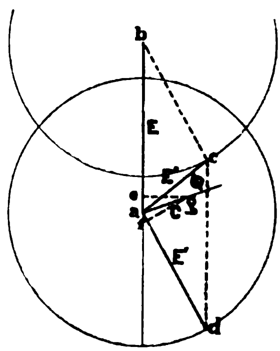
FIG. 4.

In Fig. 3, E and E' are equal , the armature and line circuits have no appreciable resistance, and self-induction is present. At the instant of synchronism and connection of the motor to the generator circuit no current will be established through the motor because the generator and counter E.M.F.'s are equal. The motor armature will lag to a point where the resultant pressure is E''. E'' will establish a current C one quarter of a period behind itself. Such a current will have a large component that is negative with respect to the motor pressure and in unison with that of the generator. An early point is reached at which the

motor will do good work. Later on a maximum component of this current, that is opposite to the motor pressure, will be found, beyond which the motor will lose synchronism.

In Fig. 4 E is greater than E', the circuits possess no resistance, and some self-induction is present. At the instant that the motor is synchronized and connected the resultant pressure E'' is the algebraic difference between E and E'. E'', because the circuit possesses self-induction with no resistance, will establish a current through the motor, at right angles to itself and the motor and generator pressures. No power from such a current can result. The armature will lag to a later position where the conditions are found to be practically the same as those discussed in connection with Fig. 3.





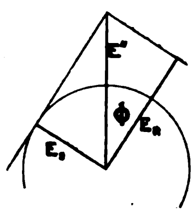


FIG. 5.

FIG. 6.

In Fig. 5 E equals E', and resistance and self-induction are both present in the circuits. Since E and E' are equal, no work can be done until the armature lags to some position d, where the resultant E.M.F. is E''. When the E.M.F., resistance, self-induction, and periodicity of a circuit are known, the impedance is known, and the current becomes known from the relation

$$C = \frac{E}{Impedance}.$$

The phase position of the current is determined by the ordinary construction $E''E_s E_r$ of Fig. 5. The projection of C on to E' is a quantity that is proportional to the developed mechanical power. This projection, as in all other cases, at a certain position attains a maximum beyond which the motor will come to rest.

In the last diagram, Fig. 6, E is greater than E', and self-induction and resistance are present. In general, the position of the armature at no load will be in advance of the normal position of synchronism, the position of advance being limited as in the similar cases cited above, and which the figure fully illustrates.

In practice the relation of the magnitudes of E and E' are determined by the field excitation and the currents that are established through the motor. Armatures that develop powerful reactive effects upon their fields in action equalize the motor and generator pressures, and such armatures must necessarily possess considerable self-induction. These are the requirements for suitable working as indicated by the above analysis.

It is well to suggest, also, that the amount of the mass of the revolving parts of a synchronous motor have an additional effect upon the stable operating conditions. During every complete period there are two short intervals throughout which the motor in general must act as a generator and give back a small amount of power to the generator. The only source of this power is the fly wheel property of the revolving parts of the motor. Multiphase motors are independent of this fly wheel effect because at no instant does the motor do work on the generator, while on the other hand the amount of mechanical energy developed instant after instant is practically uniform.

COLLEGE TECHNICAL JOURNALISM.

BY EUGENE B. CLARK.

All college publications may be divided, from the standpoint of the technical man, into three classes: those whose character is general, such as newspapers and literary magazines; those which, while publishing news of general interest, also include matter of technical or semi-technical interest; and those which are purely technical in their composition. The last named class includes all such as medical, law, or engineering papers. As will easily be seen, the remarks which are to follow, while they refer particu-

larly to engineering journals, will often apply to the whole class of publications that is included under the head of college papers.

College journalism differs quite radically in many points from journalism that is followed as a means of making a living. The college editor labors under disadvantages as well as advantages.

In the first place the method by which the editor obtained his place does not insure ability. Probably he has been elected from among his fellow classmen by popular vote or because he and his friends have "hustled;" or he may have won over a few other candidates by competitive trial. In either case his selection does not carry with it any guarantee of literary or business ability, though those qualities may affect the choice to some extent. As a consequence of this fact the editor very frequently embarks upon the editorial sea with no experience to assist him in steering a straight course to success.

As the second difficulty to be overcome in publishing the college paper we will mention the business side of the enterprise. The income is not large and consequently must be economically disposed of. Upon the activity and ability of the business manager the paper is dependent, to a large extent, for the attractiveness of its appearance, for the amount of reading matter offered and the form in which it is presented, and, in fact, for the general prosperty of the publication.

Another obstacle with which the editor is compelled to cope is that of determining the scope of the journal. There is the opportunity here for the display of nice discrimination, for it must be kept in mind that the readers are not all of the same class; some are in college while some are out; some are at the threshold of the profession while some have laid the foundation, and are building the superstructure of experience that is essential to every man's education. The final difficulty in the way of the publication of the college journal consists in the fact that the management changes so frequently. This perhaps, is the most serious of all.

Thus we have seen that there are obstacles to be overcome in this work as in all others, and in view of the fact, we naturally are led to imagine whether or not success has rewarded the efforts in this direction. A glance at the list of college technical journals that is included in this article would seem to indicate that, although all such papers do not labor under the same disadvantages, still the results are as satisfactory as could be desired.

When we look to the other side we see that the college editor

possesses peculiar advantages which make the paper of especial value to its readers. The reading matter, which is obtained from three principal sources, is easily secured and of a high order, being of particular interest to the readers. It may be obtained from the teaching force, for that body, by reason of its interest in the school and its work, feels an active interest in the welfare of its organ, and is always ready to contribute generously to its pages; it may be obtained from advanced students who wish to exhibit the results of some extended compilations or some original researches: or it may be obtained from the lectures of the prominent engineers who visit the large institutions. Any one of these sources is fruitful of valuable and original engineering information.

In regard to the financial problem also, the college business manager has some advantages to offset the disadvantages arising from small revenue. The student paper is offered to its reader practically at cost,—sometimes a little more, sometimes a little less—but as a general thing for the actual cast of publication, for there is no extensive corps of assistants to be paid, no heavy office rents to be met, nor are there nearly so many incidental expenses; the only expense is that of printing, and that is largely met by the money received from the sale of advertising space.

As for the disadvantage of the frequently changing management, that is provided for, in the case of most publications of this class, by the fact that the junior members of the board obtain some experience which they are free to apply when they become the senior members.

The benefits accruing to the publication of a college organ are many. In the first place some means of publicly expressing opinion, and of having the opportunity of reading the expressed opinions of others and the news of the college has come to be considered a necessity. Every college, no matter how small, has some publication, and the larger ones support, besides several general papers, one or more of special interest. The particular value of the latter class becomes apparent immediately upon consideration of the question. While in college a man wants to know the local news, the events concerned with college life that happen from day to day. The only source from which to obtain this is the college newspaper—sometimes a daily; more often a weekly or monthly.

The ambitious professional man, student or practitioner, finds it necessary to keep himself informed of what is going on in his

line of work, by subscribing to and reading journals published in the interest of his profession. It is well-known that the college student belongs to an exceptionally ambitious class ; this is shown clearly by the fact that they support journals that are, as a general thing, of a high order of merit. What paper could be better suited to the needs of a student than one published by students for students? Its pages are open for the contributions of the more ambitious students. It is here that the future leader in his profession may develop a talent that will have much to do with his future success—that of giving his knowledge to his fellow-men through the instrumentality of the press. To see a man's name frequently among the list of contributors to scientific papers at once gives the observer the idea that there is a man who intends to push himself to the front, or that he has already done so. This is true in college as well as elsewhere. It stands to reason that, with contributors who are already well known authorities in their lines, and with those who intend to make themselves so, a college paper of this class becomes valuable in itself. Bound volumes placed in a library serve as valuable reference books.

In the case of those who have gone out as graduates, the college organ serves to keep alive the pleasant associations and remembrances of university life, that every old college man, who maintains a feeling of love for his Alma Mater, holds so dear. It also offers a medium through which he may obtain information concerning his class-mates. This last consideration is a most important one, for by maintaining the unity, and consequently the strength, of a body of alumni, we will be increasing that feeling of union among the graduates which accounts so largely for the prestige of the older universities. Anything that will foster this feeling in a body of alumni should be encouraged as a blessing.

In closing these remarks it might be well to take a look around and see how many publications exist that might be called technical journals, and see how they are managed. We will confine ourselves to engineering journals as being of special interest just at present.

Columbia College, in New York City, is represented by the *School of Mines Quarterly*. This publication contains much valuable matter of scientific and engineering interest. It was founded in 1879 by the students of the School of Mines, and for two years was edited and managed exclusively by students selected by the Engineering and Chemical Societies of the School. In 1881 the Association of Alumni obtained a one-third interest, and in 1892

the entire management passed into their hands. The journal is edited by a committee appointed by the Association, usually, but not necessarily, officers of the School. Students' contributions that embody useful compilations or valuable original research are published, and great prominence is given to articles useful to students in their work.

The *Technology Quarterly*, of the Massachusetts Institute of Technology, was established by the students of the Institute, and for two years was operated by them. It passed into the hands of the Society of Arts, which by charter is a part of the Massachusetts Institute of Technology, and is now published by a committee selected by that Society. The committee consists of five members, three of whom are members of the faculty enrolled as members of the Society of Arts. The matter published consists of articles of value to the various departments of the Institute, and of papers read before the Society of Arts. From these sources much of permanent scientific value is obtained.

The Stevens Institute of Technology is represented in the field of technical journalism by the *Stevens Indicator*. This magazine is the official organ of the Alumni Association of the Institute, and is published quarterly by a board of five editors. The editor-in-chief is chosen by the Alumni Association from among its members in the near vicinity of the Institute, or from the faculty. The remaining editors, one from each class of the Institute, are chosen by the retiring board from two candidates presented by each class. The matter published consists of contributions from the alumni and faculty, and of abstracts of theses, and possesses high merit.

The *Technic*, of the University of Michigan, is an annual, published under the auspices of the engineering societies of that institution. This publication was established in 1885, under the name of a *Series of Papers Read before the Engineering Society of the University of Michigan*, but in 1888 the name was changed to the *Technic*, by which it has been known since that time. It contains articles of engineering interest contributed by the students, alumni, and members of the faculty, and aims to embrace as many reports of original research as possible. Each volume contains a full page photo-engraving of some member of the faculty, with a short sketch of his life. The *Technic* is controlled and edited entirely by engineering students. The board of editors consists of a managing editor, selected by the previous board ; the President and the Corresponding Secretary of the Society; together with a business manager and a junior member, appointed by the other

three editors. The junior editor becomes the managing editor of the next year's board. A glance at the *Technic* shows it to be a decidedly well edited book containing much that is of permanent value, coming as it does from the faculty, alumni, and students of the engineering department of a great university.

Another technical journal that is published by student engineering societies is the *Technograph* of the University of Illinois. This publication was established in 1887 as the *Selected Papers of the Civil Engineer's Club of the University af Illinois*. In 1891 the name was changed to the *Technograph* and the Mechanical Engineers' Society joined in the publishing. Later the Architects' Club was included. The paper has always been under the editorial and financial control of the undergraduate students and the greater part of the contributions have been from their pens. This annual is another example of the excellent work accomplished by engineering students.

At Lehigh there is an engineering annual known as *The Lehigh Quarterly*, which was established in 1890 as the organ of the Engineering Society.

THE SIBLEY JOURNAL OF ENGINEERING is the organ of Sibley College, Cornell University, and as such represents the interests of the students in the electrical and mechanical engineering departments. It is, so far as is known to the writer, the only purely technical college journal published monthly and under student control entirely. Cornell is also represented by the annual of the Association of Engineers (civil), and that of the Electrical Society, the latter to be published this year for the first time, as the society has just been organized.

We can do no more than to mention one or two of the semi-technical papers such as the *Rose Technic*, of Rose Polytechnic Institute, the *Polytechnic* of Rensselaer Polytechnic Iustitute, and the *Georgia Tech.* of the Georgia School of Technology.

Abroad there are, so far as the writer has been able to learn, no student technical papers, though there are one or two college journals published by the faculties, there being one at the Ecole Polytechnique of Paris, and one at Munich.

In glancing over the above summary we find three and possibly four, journals that are entirely under student control, three of which are annuals of engineering societies. The list, while undoubtedly incomplete, will, it is hoped, give some idea of the activity displayed by engineering students in making public their work, and in seeking to know the work of their fellow students and their predecessors.

RARE COPPER ALLOYS.

Pure Copper has its properties affected by small doses of the Rare Metals, tested in the form in which maximum tenacity is exhibited, according to Mouchel, thus: *

PROPERTIES OF RARE METALS.

Annealed wire, Diam. 0.5 mm. alloyed with 0.1 per cent. of	Resist. per kilom. at 0°C. in ohms.	Conductivity.	Elong. Per cent.	Tenacity in Metric Measures.
Lead, ...	78.21	104.04	36	19
Molybdenum, . .	78.78	103.28	34	22
Cobalt, ...	79.17	102.77	38	20
Silver, ...	79.30	102.60	4	29
Sulphur, ...	79.31	102.59	38	22
Gold, ...	79.35	102.54	32	21
Selenium, ...	79.43	102.44	30	27
Thallium, ...	79.44	102.42	36	21
Zinc, ...	79.59	102.22	35	27
Antimony, ...	81.30	100.08	30	23
Tellurium, ...	81.50	99.84	2	41
Platinum, ...	81.98	99.25	39	20
Nickel, ...	82.72	98.37	39	22
Tungsten, ...	84.08	96.77	36	22
Tin, ...	84.49	96.31	4	32
Chromium, ...	85.64	95.01	34	23
Magnesium, . . .	86.29	94.29	34	36
Aluminum, ...	89.86	90.55	35	22
Manganese, . . .	90.09	90.31	34	28
Iron, ...	97.65	83.32	33	22
Arsenic, ...	105.17	77.36	39	22
Silicon, ...	120.44	67.55	21	18
Phosphorous, . . .	149.54	84.30	31	23
Bismuth, ... ⎫ Cadmium, . . . ⎬ Potassium, . . . ⎬ Sodium, ... ⎭	Umanageable.			

In this series the "pure" copper had a conductivity of 104, as compared with the standard at 100. Copper itself has been found to possess little value, unalloyed, for general purposes. The above series of figures have value as showing the general effect of alloying it with other, and as yet unfamiliar, metals; some of which, it might be thought, should have value when used to lighten and strengthen the more familiar metals. The most promising alloy on the list for constructive purposes is that which contains tellurium; the next is the alloy with tin; the next with silver; the

*U. S. Report on the Paris Exhibition of 1889, iv, 231.

next manganese ; the next zinc. But the tenacities have a range in these cases of from about 65,000 pounds per square inch, with tellurium, to 40,000 pounds with zinc and tin.* Unfortunately, titanium is absent from the list. Of the common metals, alloys with tin are most promising. We are already familiar with them and know that they cannot compete with the steels in construction.

The engineer having to do with electrical machinery is interested particularly in the conductivities of these alloys, and finds that many of them, as those containing silver, gold, zinc, and especially tellurium, combine high conductivity with great tenacity. The aluminum and still more the magnesium alloys excel in combined strength, conductivity, and lightness.

The above figures are taken from a paper by Dr. Thurston, read before the Aeronautical Congress at Chicago in 1893, and of which an abstract—not containing these data—is published in the journal *Aeronautics* for March, 1894.

WORK OF COLLEGE PROFESSORS.

The *Railroad Gazette* says, in answer to a criticism upon the *Proceedings* of the A. S. M. E. to the effect that it contains too many papers, by college professors and others, which are of a mathematical nature or which give the results of school tests :

"Those who cannot read mathematical or theoretical papers understandingly will find such papers of little value to them, but the great body of engineers are good mathematicians, and probably the best and quickest way to get a practical grasp of a new subject is to encourage our professors in technical schools, to whom we owe more than most of us are willing to acknowledge, to go before us and dig out the true inwardness of things and smooth the pathway for those who are to follow on with the practical application to commercial uses. Every engineer will acknowledge his indebtedness to the mathematical and theoretical work done by others and which he has put into practical use, and it is to be hoped that the papers by college professors, whether giving "school tests" or those of a "mathematical or theoretical order" will increase rather than diminish. The hope for the usefulness of any engineering society lies in the encouragement of that class of work as much as of any other."

*To obtain the tenacity in British measure ; multiply the figure in the list by 1422.3.

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Box 1501, Ithaca, N. Y.

THE editors desire to call attention to the provisions of the recently adopted constitution for the SIBLEY JOURNAL in regard to the elections to the board for next year. The time that has been set for the election to take place is on Tuesday, May 29, from 11.30 A. M. to 2 P. M. in Sibley College. All candidates are requested to give their names to E. B. Clark, 15 Huestis St., by noon of Monday, May 28. The competition for place on the board will be closed at twelve o'clock on May 29.

EDITORIALS.

OUR ALUMNI AND THEIR ALMA MATER.

THE circulation of the SIBLEY COLLEGE JOURNAL OF ENGINEERING is a measure, in some degree, of the interest felt by the Alumni of the College and the University in their Alma

Mater. The active, earnest, whole-souled graduate of this, as of any other, college, appreciates the fact that, however much he may have himself paid for his education, the Founders of the institu- of learning in which he has thus been prepared for the duties of life, have done much more for him than he has for himself. They have not only done this by securing for him these unexampled opportunities but by actual contributions in money to the full extent of the difference between the fees which he pays into the treasury and the actual costs of his education. This difference amounts to $1000 or $1500 for each student graduating from the college.* But if the student were to pay the full amount of the actual outgo, his indebtedness for the opportunities provided him would be more serious than the cash expenditure. Many graduates are grateful and appreciative of what they know has been done for them by Cornell University and Sibley College; but comparatively few realize how great is their obligation, measured in either way. Not many have sufficient interest, after leaving the college and getting into the whirl of business, to keep up their connection with Alma Mater through the college papers; and very few ever give much thought to the possibility of doing something, ultimately, for the institution which has done so much for them.

The subscription list of the SIBLEY JOURNAL is strangely short, outside the limits of the Campus, when we consider the great number of possible subscribers. Every Sibley College man should make it a point on going out into business, to leave his subscription; both in order to aid in supporting an important and desirable adjunct to the College, and to insure constant familiarity with its status and work and growth. He should also hold, as an integral and essential part of his plan for his coming life, that of, some day, doing what his means may allow to promote the splendid work which is carried on here. If he cannot endow a professorship, he may sometime found a fellowship or a scholarship. If he cannot give a million for extensions of Sibley College or the promotion of research, he may at least contribute a piece of useful apparatus. There is no way in which a man can do more to promote the best interests of his fellows than by contributing what he can to elevation and extension of higher education, and especially of technical education of every grade,

* In 1893 the University graduated about 300 students and paid out a half million dollars—$1700 per graduate.

from manual training to engineering schools. There is no way in which a man can secure a more permanent and satisfactory memorial of the life which he is trying to make useful to his fellows. Every alumnus should not only take interest and pride in sustaining the honor and the reputation of the College; but every one should do what he can, in his own way, small or great, to advance her every interest.

A pamphlet by the Director of Sibley College has just been printed by Munn & Co., of New York, on "The Needs and Opportunities of a Great Technical College," exhibiting the condition and work of Sibley College, which all should make use of in thus promoting that work and in the endeavor to secure for the University and the College additions to its endowments and to its facilities for providing for every ambitious student the opportunity to prosecute whatever line of study and research he may find desirable.* The extent and the equipment of Sibley College are already very great; but they are not yet sufficient to meet the demands of a student body of six hundred. Still more building space is needed; still more extensive equipment is necessary; and, more than all, a very much larger staff of instructors should be provided as soon as the means at the disposal of the Trustees can be made to supply them. The opportunities now particularly attractive to the administration are those which offer to add to the present organization the long contemplated schools in special lines of engineering. The cost and the difficulties of institution of a school of locomotive and railway engineering and machine construction would now be small; since the College has already the larger proportion of the staff and the outfit needed in teaching such a course. The same is true of other lines of work, as chemical engineering, mining engineering, the science of cotton and wool manufacturing, and many other important departments for which we have great demand, in this country—a demand which has in most of these directions never been met or attempted to be met. The opportunities of Sibley College, already the largest and best known institution of its kind in the country—perhaps in the world—are greater than can readily be comprehended, greater than its best friends probably realize. All that is needed is capital. Alumni of Sibley! provide it by your own contributions and by securing us new friends.

* For copies address the Director or apply to the SIBLEY JOURNAL.

For several years past, the SIBLEY JOURNAL has been managed without a complete constitution to serve as a guide, (the only one being that adopted in 1889, which has proved insufficient during recent years). It seems almost impossible that such a state of affairs should exist, especially since there are often points that come up for the board of a college publication to decide that involve considerable thought, and sometimes, difference of opinion. Consequently, although we point with some pride to the fact no trouble has ever occurred, still we acknowledge the advisability of a constitution. For these reasons the constitution, which is included in this issue of the JOURNAL, was drafted and presented to the student body of Sibley College in mass meeting assembled, and was adopted by them. No apologies are made for including it in the contents of a number of the JOURNAL, for it is believed that every student and alumnus of the college who subscribes to the JOURNAL will be interested in knowing upon what basis the publication is managed. Also, if it is published, there will be no chance of its ever being lost. It is our duty to state that the board immediately preceding this one contemplated this action and that they laid the foundation which we built upon in forming the present document.

GRADUATE M. E.'S AT SEA.

In the last convention of the U. S. Supervising Inspectors of Steam Vessels, the Committee on Boilers and Machinery, having had under consideration the resolution of John W. Oast, Supervising Inspector of the Third district, on the 30th day of January, 1894, recommended the adoption of the following as a substitute for section 5, Rule V:

Provided, That any person who has served as a regular machinist in a marine-engine works for a period of not less than three years, and any person who has served for a period of not less than three years as a locomotive engineer, stationary engineer, regular machinist in a locomotive or stationary engine works, *and any person who has graduated as mechanical engineer from a duly recognized school of technology* may be licensed to serve as engineer on steam vessels after having had not less than one year's experience in the engine department of a steam vessel, which experience must have been obtained within two years preceding the application (which fact must be verified by the certificate in writing of the licensed engineer or master under whom the applicant has served, said certificate to be filed with the application of the candidate); and no person shall receive license as above, except for special license, who is not able to determine the weight necessary

to be placed on the lever of a safety valve (the diameter of valve, length of lever and fulcrum being known) to withstand any given pressure of steam in a boiler, or who is not able to figure and determine the strain brought on the braces of a boiler with a given pressure of steam, the position and distance apart of braces being known; such knowledge to be determined by an examination in writing and the report of examination filed with the application in the office of the local inspectors, and no engineer or assistant engineer now holding a license shall have the grade of the same raised without possessing the above qualifications.

The provision thus recommended was adopted and the graduate of Sibley College may aspire to this honor—if he can compute the elements of the safety-valve, and the safe proportions of a boiler. Several Sibley College men have engineered their own steam yachts and others have had experience on sea-going vessels.

The committee of the general faculty on scholarships May 4th recommended to the general faculty the following assignment of fellowships and scholarships for the ensuing year:

One fellowship was assigned to each of the following departments or groups of departments: Romance Languages, German Languages, Mathematics, Chemistry, Physics, Civil Engineering, Zoology and Entymology, Botany and Geology, Architecture, English, Agriculture, Horticulture, and Veterinary Science, and two fellowships to Mechanical and Electrical Engineering, (Sibley College).

The ten $300 graduate scholarships were assigned one each to the following departments or groups of departments: Mathematics, Chemistry, Physics, Civil Engineering, Latin and Greek, Archæology and Comparative Philology, Zoology and Entymology, English, Botany and Geology, Sibley College.

It was also decided to recommend that graduate scholarships which shall be accompanied by the remission of tuition be assigned to each of the existing departments or groups of departments to which a fellowship is now allotted and in the same proportion. It was also recommended that, in case of the failure of any department or group of departments to recommend a fellow, the general faculty fill the vacancy. Sibley College thus, for the first time in its history, has fellowships definitely assigned to it. With one-third the registration of the University and a very large fraction of the total list of applicants for graduate work and for fellowships, Sibley College has rarely had one-tenth the total fellow-

ships and sometimes not one out of the whole list, which now numbers 23.

THE Census Office, after long delay, has issued the first bulletin giving the wealth of the United States in the year 1890. The true valuation, that for which it is supposed the property would sell in ordinary states of the market, is stated to be $65,037,091,-197; of which $39,544,544,333 represents the real property, and of which $25,492,546,864 is personal property. The assessed valuation was but $25,473,173,418; and of this, about $19,000,000,-000 was realty, and $6,516,616,743 was personal property. The valuation was thus about 40 per cent. on real property, and only 25 per cent. on personal property; this difference indicating the extent to which the latter class of property escapes taxation. Railroad property is valued at about $8,700,000,000 and mill property at about $3,000,000,000. The totals have increased from seven (1850) to sixteen, thirty, forty-three and sixty-five thousand millions, decade by decade, since the middle of the century; and the value *per capita* has risen from $300 to $500, $800, $900, and $1000, in round numbers. The wealth of the country is still increasing at the rate of about fifty per cent. per decade. It is to-day (1894) probably not less than $80,000,000,000 and greater, *per capita*, than that of any other nation on the globe.

THE American Society of Mechanical Engineers has issued its regular ballot list, in advance of the Spring Meeting, to obtain by mail the votes of members on the candidates, of whom a long list—about forty—is given. It is not permitted to publish names from this list, as there is always a possibility of some rejections; but we observe, as usual, a fair proportion of Cornell and Sibley College men among them, and the names of the active members of the society representing the Faculty and the University appear frequently as proposers and seconders of nominations. It is becoming more and more usual for our graduates to enter these professional societies at graduation, they being then immediately eligible for election as Juniors. It is considered a very great advantage, from a professional point of view, to hold membership, especially as it gives opportunity to make valuable acquaintances and to take part in the preparation of papers and as it entitles one to the now extremely valuable *Transactions*.

CRANK SHAFTS.

—A letter to the Director from a friend in the engineer department of the U. S. S. Marblehead, reveals the critical condition of the navy in respect to its engineer corps. The ship carries three engineer officers and a crew in that department of seventy-five men; and there are forty engines, beside the main engines and the ship's boilers, to be cared for by these three officers and their men. The engineer officers are still leaving the service; matters are going too, from bad to worse, and the national legislature quietly looks on and does nothing. Quotations in this JOURNAL from the last report of the Engineer-in-Chief of the Navy, although very impressive, were hardly as much so as the above facts.

—The relations of strength to composition of cast-iron has been very little studied, and every item of information on this subject is worth preserving. Major Rodman, in his reports of materials for cast-iron ordnance, gives about the only really useful information in regard to American irons now extant. (See Thurston's Materials, articles on cast-iron). The following just received from a Sibley College graduate will be likely to find place in many note books: Composition of charge—Olive, No. 2, 1,000 lbs.; Salisbury, No 2, 500; No. 3, 1,000; Castle, No. 1, 1,000; No. 2, 500; Niagara, No. 2, 1,000—5,000 lbs. Tenacity, 18,750 to 20,080 lbs. per sq. in.; transverse, 2,050 to 2,200 lbs. on test-piece $1 \times 2 \times 24$ inches; deflection, 0.44 to 0.48 inches. The charge was melted in a Collian cupola, with Lehigh coal.

—The organization has just been completed, at Springfield, Ill., of the National School of Electricity, an organization growing out of the electrical department of the World's Fair. Professor Barrett, chief of the electrical department of the World's Fair and chief electrician of Chicago, is at the head of the organization, and Mr. Thomas A. Edison heads the honorary faculty. This faculty is made up as follows: Mr. Edison, dean; Mr. Nikola Tesla; Dr. Gray, of Highland Park; Prof. Carhart, of Ann Arbor; Prof. Anthony, of New Jersey; Prof. Ryan, of Cornell; Prof. Perrine, of Leland Stanford, Jr., University; Prof. Shephardson, University of Minnesota; Prof. Thomas, University of Ohio; Prof. Jackson, University of Wisconsin; Prof. Ayres, University of Louisiana; Prof. O'Dea, University of Notre Dame, and Prof. Barrett. It is the intention of the founders of the school to inaugurate classes in electricity in every city and town where the population will justify it. This enterprise was started as the out-

come of a popular demand for information upon electrical matters. It is proposed to establish courses in the practical and theoretical sides of electricity that will be open to every one upon the payment of a nominal fee. Several such schools have already been put in operation in Chicago. Professor Ryan, though belonging to the honorary faculty, takes no active part in the work.

—Remarkable in the extreme is the progress that has been made in recent years in connection with the manufacture of cotton goods at the South. It is no more than the simple truth to say, that there is no other Southern industry that has exhibited such a healthful advancement as this since about 1880. A well-informed writer who has recently gone over the subject very carefully says that in 1880 the South had 161 cotton mills, and 667,854 spindles. By 1880 they had increased in number to 255 mills, with 1,766,553 spindles. The South now has 406 mills, with 9,763,879 spindles and 62,052 looms. In addition to this the mills projected will have between 50,000 and 75,000 spindles. The increase in spindles last year was over 200,000. . . . . The capital invested in cotton manufacturing in the South has increased from $21,976,-712 in 1880 to $97,000,000 in 1894. Thirty-two mills have reported their dividends for 1893, the average being 8.8 per cent., in addition to which most of them laid aside as a surplus for repairs or extensions. Two mills paid 20 per cent.; one 18 per cent., while the others ranged from 12½ to 4 per cent. By far the most important undertaking yet set on foot in this particular field is that of the Courtenay Manufacturing Company, of Newry, S. C. This company was incorporated in April, 1893, with a capital stock of $150,000, which was increased in December last to $200,000. It has at Newry, Oconee County, S. C, one of the finest cotton mill properties at the South, and intends to produce a finer class of goods than any heretofore made in that section. . . . . The plans, specifications and personal superintendence of this new industrial enterprise were entrusted to Mr. W. B. S. Whaley, a rising mill engineer, who has also just finished the new mill at Union, S. C. He is a Charlestonian, educated at Cornell (Sibley College, 1890), and has spent five years in New England mills for practical experience.—*Mercantile Times.*

—The great "Testing Machine" exhibited at the World's Columbian Exposition at Chicago, last summer, in the government building, designed by Mr. Albert H. Emery and built by the Messrs. Sellers of Philadelphia, is about to be sent to Sibley College, to complete its equipment in this direction. It is probably

the most delicate and accurate testing machine in the world, and is considered the only type of machine capable of doing some kinds of work in which peculiar and absolutely scientific accuracy is exacted. With a load of a hundred tons on its holders, the hand of a child can produce measurable and weighable movement of its weigh-beams. While breaking a bar of iron, the weight of a coin will introduce sensible disturbance. This machine was, throughout the exposition, in charge of Mr. Preston, the senior instructor in the mechanical laboratory ot Sibley College. He will welcome it as an old friend whose ways he knows perfectly. In his hands it will probably do excellent and important work in research. The other machines of that laboratory are mainly for the work of instruction in standard methods, and for commercial work; but this and the Emery standardizing machine, already the property of the laboratory, thanks to the liberality of the makers, the Yale & Towne Company, of Stamford, Conn., give that laboratory the best outfit for scientific investigation, possessed by any establishment of any kind in the world. The "standardizing machine" is that upon which all the Emery testing machines in the country have been standardized and given their rating. The new machine, although not as large as the government machine at Watertown, is probably even more perfect in construction and more delicate and accurate. The generosity of the makers of this machine, the gift by the McEwen Co. of the new 100 horse-power engine, and the present, just announced, of some $500 worth of steam engine indicators, by one of the most famous firms in the line of work, as well as many thousands of dollars worth of machinery from other sources during the last few years, give good reasons for expecting continued and increased support from these outside sources in the future.—*Ithaca Journal.*

PERSONALS.

'88.

Edward Caldwell, P. G., is editor of the *Street Railway Gazette*, published in Chicago.

I. P. Disney is Third Assistant Patent Examiner in the U. S. Patent Office. He is in the boot and shoe section.

S. B. Fowler, P. G., is Assistant Superintendent of the Chicago Telephone Co., and directs their underground department.

Geo. W. Bissell. We take pleasure in offering to our readers in this issue a contribution from the pen of a former editor-in-

chief of the SIBLEY JOURNAL, then known as the *Crank*. Mr. Bissell was a member of the class of '88, and is at present a Professor of Mechanical Engineering at the Iowa Agricultural College, Ames, Ia.

'89.

W. M. Dollar (non. grad.), since leaving the University, has had varied and profitable work in the line of his profession. Between January 1 and April 15, 1890, he was in charge of the erecting shop of the D. S. Mergan Co., Brockport, N. Y. He spent seven months as draughtsman and machinist with the Governeur Machine Co., at Governeur, N. Y., and was then put in charge of their works, where he remained till March, 1894. Since then he has been master mechanic with Pratt & Letchworth, Buffalo, N. Y.

'90.

Joseph Kuhn is in business at Lima, Ohio, and is enjoying his opportunities of good work with the Solar Refining Co. of that place. He was for a time, after graduation from college, with the Edgar Thomson Works at Pittsburgh, but has been for more than a year at Lima. He reads the SIBLEY JOURNAL, and keeps well-informed of the progress continually making in the college.

'92.

F. H. Parke is with the Westinghouse Electric and Manufacturing Co , Pittsburg.

A. D. Lunt, (P. G. '93), is Fourth Assistant Patent Examiner in U. S. Patent Office.

Geo. W. Bacon has recently become one of the firm of Ford & Bacon, 421 Chestnut street, Philadelphia, dealers in electrical supplies.

Francis H. Boland, (P. G. '93), has, since leaving the University, been a valued employee of the DeLa Vergne Refrigerating Works, New York City. He has lately broken in health and is now on leave, recuperating.

Geo. L. Thayer is in business for himself as electrical engineer, specializing in power transmission. He will do consulting and contracting work in street railway and electric lighting respectively. At present he is retained as consulting engineer by an electric road near Chicago, which is intending to adopt a storage battery system and run their charging plant by a gas engine. Prior to this start for himself Mr. Thayer was employed by the West-

inghouse Electrical and Manufacturing Co. His office address is 1439 Monadnock Block, Chicago.

'93.

J. W. Smith is engineer of the Edison Electric Illuminating Co., of Newburgh, N. Y.

F. N. Jewett is employed by B. W. Payne & Sons, engine and boiler builders, Elmira, N. Y. His work is divided between the drawing room and the testing department. It is by this firm that the three cylinder engine for the Cornell launch is being built.

W. F. Evans, (non-grad.), is a member of the firm of Witherspoon & Evans, consulting and supervising engineers, New York City. He has for a long time been cable expert for the Safety Insulated Wire and Cable Co., and will now act both as cable expert and supervisor of electric light and power plant installations.

John Comesky (non-grad. '93) after leaving the University at the end of his sophomore year was employed by the L. S. and M. S. R. R. in the motive power department. He subsequently took a special scientific course in the Ohio State University and has taught scientific branches in a high school. He has also become well known in labor politics in Ohio.

W. Rupert Turnbull, who has been spending the last year in taking advanced work at the University, has left for his home in St. John, N. B., Canada. He is to be married on May 31 to Miss Mary Willis Davidson, of St. John. On June 2 they will sail from Montreal for England, and from there will proceed almost directly to Heidelberg where they will spend the summer. In the fall they will go to Berlin, where Mr. Turnbull expects to spend a year in the study of physics, and then, after a tour through Germany, Austria, Italy, France, and England, they will return to this country, where Mr. Turnbull intends to continue his studies. Hearty congratulations and best wishes from his many friends follow Mr. Turnbull.

'94.

Willis W. Faulkner (non-grad.), is in the office of the Erie Railroad, at Tonawanda, N. Y.

N. C. Robbins (non-grad.), is with the Western Electrical Company, New York City. His duties are confined to the switch board department.

A. W. Wyckoff (non-grad.), has spent much of the past two years in travelling. During last fall and winter he had a class in mechanical drawing in the Y. M. C. A. at Elmira.

E. G. Gilson, who completed his work at the end of last term is now employed by the Edison Electric Illuminating Co., of Boston, Mass., where he is getting valuable experience.

E. W. Roberts, who has been devoting special attention to aerial navigation while in college, intends to spend the summer in England with Maxim. He expects to obtain much practical information from his work there, and will continue his investigations in this line upon his return to this country.

'95.

Geo. M. Lukesh has been employed during the past year as draughtsman in the office of the Engineer Commissioner of the District of Columbia. The maps and drawings in the last report from this office are by Mr. Lukesh.

A RÉSUMÉ OF LOCAL EVENTS DURING THE WINTER TERM, 1894.

The winter term opened as winter terms usually do, with a vast amount of grumbling at the inexorable fates who summoned us back to the "weary grind," after a few short days of bliss, and even the lucky few, who sauntered calmly into town about the middle of January, and, gifted with greater persuasive powers than ourselves, successfully bearded the registration lion in his den, were heard occasionally to murmur.

Most prominent among the events of the term, was the unhappy Freshman banquet affair, which resulted so disastrously for the fair name of our Alma Mater. The details of the accident are so well known, that it is useless to reiterate them. In a few words, '97 announced its intention of holding a banquet, which was of course taken as a challenge by '96 to prevent it. With misguided zeal and carelessness bordering upon criminality, one or more members of the Sophomore class introduced into the kitchen adjoining the banquet hall, the noxious fumes of chlorine. One of the cooks, a colored woman, was overcome, and being unwell at the time, was affected so seriously that she afterwards died. No one else was seriously overcome, and the great majority of the banqueters knew nothing of the tragedy until afterwards.

A mass meeting of the students was called and action was taken, deploring the sad occurrence, and assuring the civil authorities of the coöperation of the students in their efforts to bring the

guilty ones to justice. It was also resolved that the annual Freshman banquet should not be discontinued, but should thereafter be held under the protection of the student body. It is probable that the sentiment expressed in this meeting will effectually prevent all future interclass demonstrations of a harmful character.

The winter term saw the dedication of the new Dairy building, an important event in Cornell's history. There were present at the dedicatory exercises a number of prominent senators and assemblymen, who represented the donor of the building, the State of New York.

In January was held the first meeting of the newly established Electrical Society, which has had a rapid and successful growth. The papers read thus far have been excellent, a number of them being from members of the faculty of the Physical Department. It has been decided to publish an annual to contain the best productions of the society, and this scheme, although rather ambitious for such a youthful organization, will doubtless meet with deserved success.

Cornell has, of late years, developed a very friendly feeling toward the University of Pennsylvania. In athletics she is our chief rival. Our crew has always to stimulate it, the threat of vengeance from Philadelphia, a vengeance which has been accumulating for many years.

In football and track athletics, to be sure, we have yielded the palm, but remember the three glorious victories at baseball last spring! There was needed one more means of deciding the vexing question of superiority, a fifth vantage ground for friendly warfare, and it was found last term, when the annual debate was arranged. The establishment of such relations with our Pennsylvania sister, cannot be too highly commended.

Junior week was replete with gaiety and enjoyment. Besides the Sophomore Cotillion and Junior Ball, there were the Masque play and the Glee Club concert. The ball was held as usual in the Armory, but the cotillion was danced at the Lyceum, amid new and pretty sourroundings. Cornell entertained her numerous fair visitors in a right royal manner, and for a week thoughts of work were thrown aside, and pleasure were the order of the day.

During March two athletic meets were held in the Gym., and many of the events proved interesting. The crews were hard at work during the whole winter and were a never-failing source of interest to the afternoon visitor to the Gym. They were able to

get out upon the water about March 10th. The baseball men were also working faithfully throughout the term and were rewarded by an early spring, which allowed them to use the field for about three weeks in March.

A worthy movement started last term, is the Witherbee Memorial project. It is proposed to raise sufficient funds by subscription, which, together with the amounts already given for the purpose as class memorials, by '92 and '93, will warrant the erection of an athletic club-house on Percy Field. The present lack of accommodations for our own and visiting athletes is a shame to the University. Nothing could be more suitable than to bestow upon this house the honored name of Witherbee.

The new examination system went into operation for the first time during last term, and did not meet with widespread popularity, nor cause any depreciation in the "bust" market. When the new regime was inaugurated by the faculty, it was understood by the deluded student body that final examinations would be abolished and that for them were to be substituted a number of "prelims," scattered through the term. In a few subjects only, was the above expectation realized. In many, the prelims were given and in addition, the whole of what had previously been examination week, was given over to a series of "one hour finals," which kept the student in a continual state of suspense. In one case one hour examinations were given for thirteen successive days. Such a "system" has very naturally caused much dissatisfaction, but it is probable that when things become altered to suit the new conditions a considerable difference will be noted.

CONSTITUTION OF THE SIBLEY JOURNAL OF ENGINEERING.

ARTICLE I.—NAME.

The name of this publication and organization shall be THE SIBLEY JOURNAL OF ENGINEERING.

ARTICLE II.—OBJECT.

The purpose of this publication shall be to represent the interests of the Mechanical and Electrical Engineering Departments of Sibley College, Cornell University.

ARTICLE III.—BOARD OF EDITORS.

SECTION 1. All active editors shall be regular students in Sibley College, Cornell University.

§ 2. There shall be six active and four associate editors.

§ 3. The active editors shall consist of one Graduate, three Seniors, and two Juniors.

§ 4. There shall be four associate editors—members of the Sibley faculty.

ARTICLE IV.—ELECTION OF EDITORS.

SECTION 1. The Editor-in-Chief and Business Manager shall each be elected by the active board from the Senior members thereof.

§ 2. There shall be two editors elected from the Junior class by the Board of Editors during the month of May, and who shall serve during their Senior year.

§ 3. There shall be one editor elected from the Sophomore class by the Board of Editors during the month of May, said editor to serve during his Junior year.

§ 4. There shall be one editor elected from the Junior class by the members thereof during the month of May, said editor to serve during his Senior year.

§ 5. There shall be one editor elected from the Sophomore class by the members thereof during the month of May, said editor to serve during his Junior year.

§ 6. There shall be one Graduate editor elected from among Graduate and Special students in Sibley College, by competition. He shall be elected before November 15th. All articles written for this competition must be sent to the Board by the 10th of November, signed by a *nom-de-plume* and accompanied by a sealed envelope containing the full name and address of writer. Failing to obtain a suitable member by competition, election may be made by a two thirds ($\frac{2}{3}$) vote of the active members of the then existing Board.

ARTICLE V.—DUTIES OF EDITORS.

SECTION 1. It shall be the duty of the Editor-in-Chief to take general charge of the paper, direct its compilation, conduct its correspondence, and preside at all meetings.

§ 2. It shall be the duty of the Business Manager to conduct the finances of the paper. He shall solicit the advertising, take charge of the printing and publication, keep strict and accurate account of all moneys collected for, expended by, and belonging to the paper, and notify each member of the Board of all business meetings.

§ 3. The duty of the Senior and Junior editors shall be assigned by the Editor-in-Chief.

§ 4. The duties of the Graduate editor shall be those of an advisory counsel.

§ 5. There shall be no duties prescribed to the Associate editors, whose presence and advice, however, will always be acceptable to the working board.

§ 6. The Board of Editors shall determine the policy and the methods of management of the JOURNAL; shall hold regular meetings at least as often as once a month, and receive reports on the preceding and on the proposed succeeding issues of the JOURNAL from the Editor-in-Chief, and on receipts and expenditures from the Business Manager, and to consider any matters of detail relating to the business of the JOURNAL that may be brought before it by its officers or members. Special meetings may be called at any time by the Editor-in-Chief.

ARTICLE VI.—MEETINGS.

SECTION 1. Four active editors shall constitute a quorum for the transaction of business.

§ 2. Each active editor shall be entitled to one vote. In cases of tie, the Board shall act under the advice of the Associate Editors.

ARTICLE VII.—MONEYS.

SECTION 1. All profits shall be disposed of as follows: The profits shall be divided into ten equal shares, of which the Editor-in-Chief and the Business Manager shall each be entitled to three, and the remaining editors to one each.

§ 2. All losses shall be arranged as the circumstances of the case may require.

ARTICLE VIII.—VACANCIES.

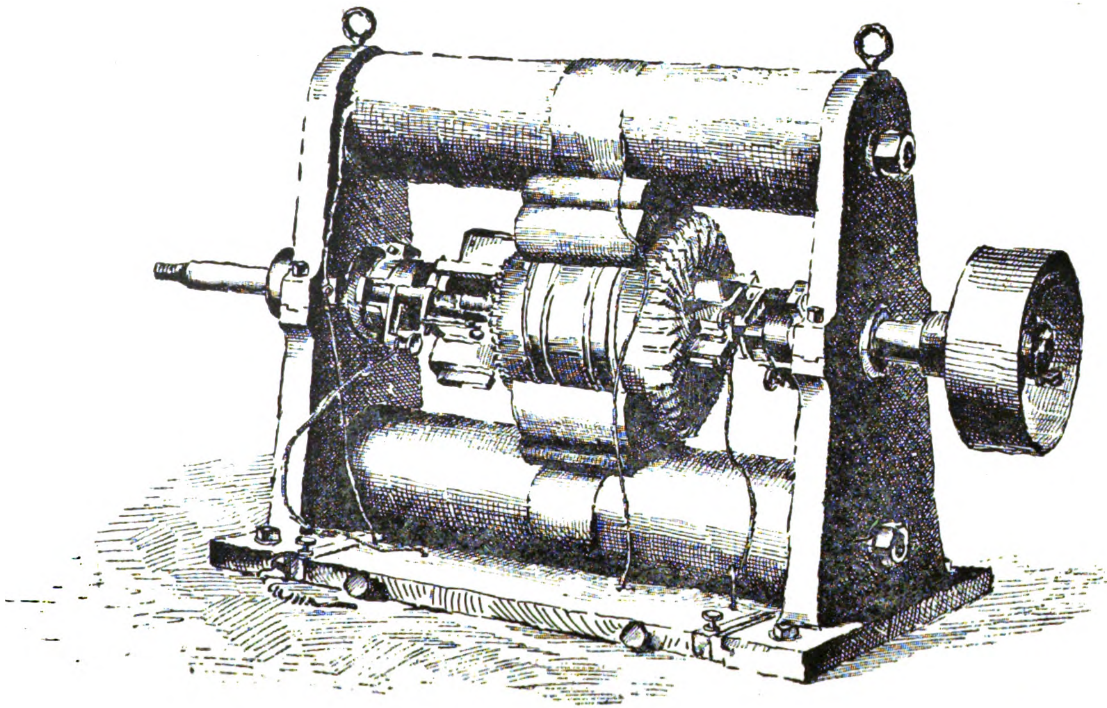
SECTION 1. Vacancies in the Board, caused by resignation or otherwise, shall immediately be filled by said Board by competitive election.

§ 2. Any editor guilty of non-performance of his duties may be, by a unanimous vote of all other active editors of the Board, expelled therefrom.

§ 3. No editor shall, after expulsion, be reinstated.

ARTICLE IX.—AMENDMENTS.

Any Article or Section of an Article of this Constitution may be amended by a two-thirds ($\frac{2}{3}$) vote of the members of Sibley College present in mass-meeting assembled, provided that such mass-meeting shall have been well advertised for one week previous to such action.



SAMPLE OF FREEHAND DRAWING DONE IN SIBLEY COLLEGE.

THE SIBLEY
JOURNAL OF ENGINEERING.

VOL. VIII. JUNE, 1894. No. 9.

IN CORNELL UNIVERSITY

"The leading object shall be, without excluding other scientific and classical studies, and including military tactics, to teach such branches of learning as are related to Agriculture and the Mechanic Arts, in such manner as the legislatures of the States may respectively prescribe, in order to promote the liberal and practical education of Industrial Classes in the several pursuits and professions in life."—[An act donating public lands to the several States and Territories which may provide Colleges for the benefit of Agriculture and the Mechanic Arts, July 6, 1862.]

PROGRESS OF SIBLEY COLLEGE.

The annual reports and inventories of the various departments of the University are now being made up, and it is a good time to give our readers, the students and alumni of Sibley College and other friends of the University, an idea of the progress which has been made, to date, in building up a College of Mechanical Engineering at Cornell. We have obtained these figures, in part, from the last report of the President to the Board of Trustees, later circulated in pamphlet form, and we have obtained others, no less interesting, from other accessible documents. The following is the condensed statement of the growth of the undergraduate body of students in Sibley College, to date, as given by the annual registers and reports since the date of organization of the College, 1885-6.

	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94
Enrolled, ...	63	106	168	220	283	369	428	501	546	556
Graduated, ...	5	19	22	32	54	52	90	93	—	

The number of graduate students has also gradually risen to about 65, the present year, and the number of "special" students, formerly comparatively numerous, has fallen to perhaps a dozen. The total enrollment for the year 1893-4 has thus been 620 for Sibley College alone, and over 1800 for the University as a whole; Sibley College having recently registered above one-third.

To the number graduating as above tabulated must be added the figures for those taking the second degree (M.M.E.). They constitute a class which was unknown in institutions of learning when Sibley College was founded, and the first graduates of this rank appeared in 1887, when three were given the master's degree by Cornell and Sibley College. The next year, six took this diploma, and the numbers have rapidly and steadily increased, until there have been for the last year or two between sixty and seventy on the list. In 1893, fourteen graduated, making the class of '93, 107 in number. Of the graduate students on the list at the present time about three-fourths are candidates for the second, and one-fourth, for the first degree, in mechanical engineering. About twenty will take M.M.E. in '94.

The magnitude and value of the college property and equipment affords an equally interesting study. When this growth of the student body commenced, the inventoried value of the college buildings and machinery—there was no mechanical laboratory with its extensive collections of experimental apparatus—was, in round numbers, $100,000. Mr. Hiram Sibley had put up the buildings at a cost of about $70,000, had installed the machinery, had given the Reuleaux collection, and had endowed the professorship of Mechanic Arts and the Sibley scholarships; the total thus given the University amounting to about $175,000. From 1885, the growth in values was as follows:

Date	Values	Date	Values
1885	$100,000	1890	$168,000
1886	106,000	1891	181,000
1887	115,000	1892	243,000
1888	144,000	1893	261,000
1889	161,000	1894	325,000

It is estimated that the property of Sibley College could not be replaced, at usual and average market prices, for $350,000; perhaps not for a much larger sum. The machinery and apparatus has been so generally obtained at no cost or at exceptionally large discounts, usually much greater than customary trade figures, that it is difficult to appraise it with accuracy. The Messrs. Sibley, the Founder and his son, have contributed, of the inventoried property, about $175,000 worth; the endowments above mentioned being added, the total becomes nearly a quarter of a million of dollars. The new building just occupied is the gift of the son; the other buildings and equipments were the contribution of the Founder.

The nearly $100,000, or more if we allow for discounts, which has been added to the inventory, and all the materials consumed and apparatus replaced in these years of active and extensive work in Sibley College have been supplied by friends of the University and College, and by purchase. The amount of the last named items is estimated at about $30 per student per annum, as a maximum. This amount is now regularly derived from the "shop fees" of students in the College, and from the share of the annual allowance from the U. S. Treasury, assigned to Sibley College; the sum of which two amounts happens, of late years, to be just sufficient to balance this expenditure. For 600 students, it amounts to $18,000 per year. This large expense for operation and extension of shops and laboratories is thus no tax on the University Treasury.

Tuition fees in Sibley College are in excess of those paid in the "general courses" to the amount of $25, and to this extent entitle those paying them to more liberal treatment. Sibley College, one-third of the University, pays about one-half the total fees received into the Treasury from students; instruction of its students costs the same as that of others, and its students pay for their materials and extras. The President's Report of 1893, of which we gave an abstract earlier, makes the net cost of Sibley College to the University, annually, about one-fifteenth the income of the University. Deducting the contributions of the General Government and of the students themselves from the total cost (for they do not come from the University at all, but are a special contribution from the Country and the students for "industrial education"), and allowing for the cost of University instruction outside Sibley College (for it provides additional instructors only; other costs are not increased), the Director's estimates make the College substantially self-supporting. But, as we noted at the time, were the cost figured at its highest, and as telling most strongly against the College, it would still be found that Sibley College students pay more and receive less from the income of the University than any others; that the College has cost the University an insignificant amount for its buildings—simply minor alterations and repairs—and, on the whole, this section of the University, instead of being, as is sometimes asserted, a tax upon the University which was originally founded especially to do such work, demands, net, at highest estimates, but two-thirds of one per cent. of the income of the University for its operation, and is less of a tax than any other body of students of equal numbers in the institution.

The "leading object" of the University and its foundation, instead of being a load upon the University, as so often stated, is being attained by taxing it for the benefit of the University at large. The real tax upon the University is the demand of the State, now a beneficiary of the University to the amount of $150,000 a year, for instruction of 500 students; for which she pays less than $20,000 per annum, while the University pays out $1700 for every one of them finally graduated.

Were the State to pay its share of costs, the University, with an income thus increased by $150,000, could do all that its friends ask of it to-day, and the proportion of the accession coming to Sibley College would give it all the new professors and instructors required, pay fair salaries to all, and found all the graduate schools of special branches of engineering, which were a part of the original plan of reorganization. Were all students to contribute as liberally to the Treasury of the University as do those of Sibley College, the income of the institution would be increased $50,000 a year and the $17,000 coming to the College would go far toward completing its undergraduate organization and establishing another school of graduate work, say in railway machinery.

Meantime, the College has grown nearly a thousand per cent. in nine years, has increased its graduating class two thousand per cent. in eight years, and now graduates, according to the reported figures for 1893, fifty per cent. more students in mechanical engineering than any other college in the land. It graduates one-third of the total from the six largest schools and colleges of the country and one-fifth or more of the total from all reported.*

These are facts which our friends will be glad to know and which they should make known publicly and widely, wherever contrary ideas have been disseminated:—Sibley College is prospering beyond hope or precedent; it is finding help and support from all sides and from all classes of people and in a thousand unexpected ways. There are even many times more farmer's sons engaged in work in Sibley College than in Agriculture, and the farmers of New York are vastly more interested in its prosperty than any other class in the community.

Sibley College contributes much more to the support of the University, per student, than any other portion of the institution; it taxes the University less, receives less than its numerical pro-

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*Technical Education in the United States. R. H. Thurston, p. 105.

portion from the Treasury, and, on the whole, it is taxed for the advantage of others. The College, as is claimed by its friends, is sending out the largest numbers of the best educated men now entering this profession. It is the largest, the leading, the most purely professional, of all engineering schools, and possesses the best facilities for higher education and scientific research in mechanical engineering.

But Sibley College needs an addition to its income for its undergraduate department of $10,000 a year; it is prepared to make good use of as much more in the organization of either of a number of proposed graduate schools of special lines of engineering; it can profitably use $100,000 in extension of facilities for graduate work; it can use a million dollars in organization of extensive schools of the mechanic arts, of trade-schools, and art-schools, such as Cornell and Sibley, and all their friends in the work, were ambitious of founding.

Make these facts known, Cornellians and Sibley men! Find us friends and show that here is the best place to make such investments in a way that shall give highest and best returns. Help the good work yourselves, and make such compensation as you can for the $1000 or $1200 that the University contributed for your own education. If you cannot do a great deal, do what little you can. Send contributions of material of all useful kinds, if only valuable in our museums. Find friends for us, and make known to them the needs and the opportunities of the University and of Sibley College.* Dollars will certainly come to us through your efforts, *and millions may come.*

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*Copies of a pamphlet describing "The Needs and Opportunities of a Great Technical College," reprinted from the Director's report of 1893, can be had of the editors or from the Director's office, and every student or graduate of Sibley College should do his share in circulating it, and thus bringing to Alma Mater support, and possibly large benefaction, and endowments, to aid those who are coming after us.

THE BEHAVIOR OF SINGLE-PHASE SYNCHRONOUS MOTORS,*

An experimental proof of Professor Ryan's analytical theory of their action,† made by the use of an Optical Phase Indicator designed by Professor G. S. Moler and Dr. F. Bedell.

BY C. E. HEWITT AND JAMES LYMAN.

The indicator‡ is an ingenious device for measuring the angular difference in the phase position of two shafts running at the same speed. When applied to a synchronous motor it gives by direct reading the angular or phase position of the armature of the motor relative to that of the generator.

It consists of two metalic discs, each fastened to a hub or collar made to slip on to the adjacent ends of the armature shafts of the generator and the motor, and held in position by set-screws. The machines are placed with their armatures in line, with the ends abutting. The discs have curved slits cut in them about one twentieth of an inch wide, and extending from points near the hub almost to the circumference. The number of slits in each disc is the same as the number of sets of poles on the machine, or the number of complete periods in one revolution. The direction of curvature of the slits in one disc is opposite to that in the other, so that the slits of one disc cross those of the other. At their intersection an opening is made that will allow a beam of light to pass through from a lamp placed on one side of the discs. Each slit extends over a complete period from its inner to its outer end, therefore when the discs are fixed to the armatures one of them must move through a complete period to cause the spot of light to travel through this range. If one revolves faster than the other the spot of light moves either toward the center or toward the circumference of the disc, and appears as a moving line of light. If the two armatures are revolved at the same speed, or synchronously, the spot of light remains at the same point and appears as a ring of light. In the case at hand, two Westinghouse Pony Alternators of the same size and type were used, having four sets of poles. The discs therefore have four slits, each of which occupies a quadrant.

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*Results of experimental work in the Physical Laboratory.

† Sibley Journal, Vol. VIII, May, 1894.

‡ The Transactions of American Institute of Elec. Engineers, May, 1894.

The curvature of the slit is that of the spiral of Archimedes. and was constructed as follows : Each quadrant was divided into eighteen equal sectors. Nineteen concentric circles were then drawn with a sharp tool on the face of the disc, thus dividing the portion of the disc lying between the extreme limits desired for the slit into eighteen annuli, each about three sixteenths of an inch wide. The slit represents a complete period of 360°; therefore the widths of the sectors and annuli represent 20°. The points of intersection of the corresponding radii and circles give the location of the slits.

An incandescent lamp covered by a hood which was fastened to the motor frame threw light upon the face of the discs, and a mirror arranged with a scale reading in degrees corresponding to the scratched circles on the discs, was set on the generatcr side at an angle of 45° with the plane of the discs, and facing them. An observer could thus see in the mirror the reflected spot of light and the phase position which it indicated. The discs were set so that the outer ends of the slits were adjacent when the two armatures stood on their corresponding neutral points, the positions being determined by the ballistic galvanometer method of field exploration.

The generator was driven by a belt from the main shaft and the motor was belted to a small Edison starting motor. The two machines were electrically connected in the usual way with the pilot lamp and spring switch, in the armature circuit. In addition, however, a considerable self-induction, produced by a small induction coil with a soft iron core, was found necessary for the steady action of the motor, and was placed in series with its armature circuit. Also a Siemens dynamometer was placed in the motor armature circuit. The potentials were taken at the brush terminals of the generator and the motor, and at the terminals of the induction coil, by a Weston A. C. voltmeter. The exciting current was also measured for each of the fields.

The coeficient of self-induction of the motor armature was found to be .00032 henrys, and that of the induction coil .00168 henrys. The total self-induction of the circuit was therefore .002 henrys.

The total ohmic resistance of the armature circuits and connections measured .21 ohms.

A run was then made to obtain the magnetization curve for the motor, with the following observed readings, which are corrected for a normal speed of 2100 r. p. m.

C Motor Field.	E E.M.F. at Brushes.	Speed.
1.	11.5	2100
1.5	16.7	"
2.	22.7	"
2.5	28.7	"
3.	34.5	"
3.5	40.5	"
4.	46.4	"

To determine the extent of the armature reaction on the field of the motor, a current of 15 amperes was passed through the armature, and with several different field excitations, the armature was turned over by hand very slowly. At the same time the A. C. voltmeter, which was connected around the brush terminals and an included resistance, was watched. No perceptible difference in the deflection was observed, so that we may neglect in the present investigation all armature reactions and take the motor E.M.F. (E') directly from the magnetization curve.

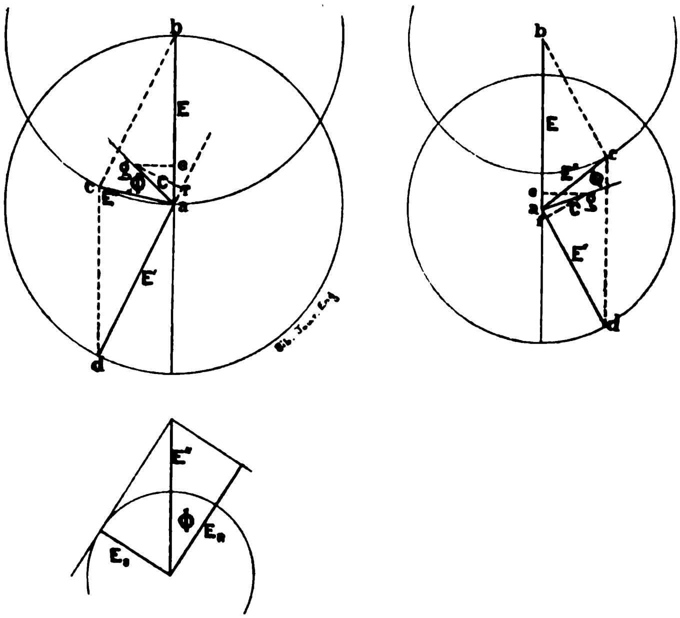

FIG. 5.

The analytical method given by Professor Ryan (see Fig. 5 and article previously referred to) requires the following measurements.

$E\ \ =$ E.M.F. at the generator brushes.
$E'\ =$ E.M.F. of motor.
$E'' =$ Resultant of E and E'.
$C''' =$ Main current consumed by motor circuit.
$\phi\ =$ Angle of lag of current behind the resultant E.M.F., (E'').

$$\omega = 2\,\pi\,n = \frac{2\,\pi \times 4 \times \text{r. p. m.}}{60}$$

We have described the way the E.M.F.'s of the generator and of the motor, and the main current may be measured.

The forces must all be in equalibrium when the machines are running, therefore the resultant E.M.F. (E'') must be just sufficient to overcome the product of the current (C''') and the impedance of the armature circuit, therefore,

$$E' = C''' \sqrt{R^2 + L^2\omega^2}$$

and the angle

$$\phi = \tan^{-1} \frac{L\omega C'''}{R\,C'''}$$

Both machines were now brought up to speed and the motor was thrown into circuit at the instant its phase position was seen by the spot of light to remain 180° behind that of the generator. At this point also the pilot lamp went out, thus confirming the disc reading. The excitation of the generator field was kept constant at 3.5 amperes, and the exciting current of the motor field was changed by increments of .2 amperes through the limits between which the motor would run, readings being taken as tabulated below.

The phase position of the motor with respect to the generator is represented exactly by the phase positions of their respective E.M.F.'s. The relative phase positions of these E.M.F.'s was easily determined by Professor Ryan's graphical method illustrated in the two diagrams (see Fig. 5). Here the direction of rotation is considered counter clockwise.

From the lower diagram E'' was taken as the resultant of the E.M.F.s (E_l and E_r) necessary to overcome the ohmic and self-induction resistances for the given current, and was the correct value of the resultant of E and E'; and the angle included between E'' and E_r gave the angle of ϕ, the measure of lag of the main current behind the resultant E.M.F. (E'').

The upper diagram gives the geometrical construction of the parallelogram of these forces; *a b* represents the direction and

LOG OF READINGS.

E Generator E.M.F.	Observed Motor E.M.F.	Observed Ind. Coil E.M.F.	C′ Generator Field Current.	C″ Motor Field Current.	Siemens Dynamometer Readings.	C‴ Main Current.	Disk Reading Angle θ.	Speed.
40.5	24.	17.	3.5	1.8	17.	11.5	185°	2088
40.5	27.	15.	3.5	2.0	14.	10.25	187°	
41.5	28.5	13.5	3.5	2.2	12.5	9.25	190°	2088
41.5	29.5	12.	3.5	2.4	10.	8.3	190°	
41.5	31.5	11.	3.5	2.6	9.	7.65	190°	2085
42.	34.	10.	3.5	2.8	8.	6.9	190°	
42.	35.5	9.5	3.5	3.0	7.	6.4	195°	2095
42.5	37.5	8.5	3.5	3.2	6.	6.05	193°	
42.5	39.5	9.	3.5	3.4	6.5	6.2	198°	2080
43.	41.5	9.5	3.5	3.6	7.	6.46	198°	
43.	44.	10.	3.5	3.8	8.	6.9	198°	2080
43.	45.5	11.	3.5	4.0	9	7.51	200°	
44.	48.	12.	3.5	4.2	10.5	8.3	200°	2090
44.5	50.	13.5	3.5	4.4	12.	9.25	200°	
44.5	52.	15.	3.5	4.6	16.	10.30	200°	2075
44.	54.	20.	3.5	4.8	18.	11.7	200°	
44.5	55.8	22.	3.5	5.0	22.	13.2	200°	2075
45.	58.5	25.	3.5	5.2	30.	14.8	205°	
45.	60.5	27.	3.5	5.4	35.	16.4	205°	2070
45.	63.	30.	3.5	5.6	40.	18.3	208°	
45.	65.5	33.	3.5	5.8	52.	20.3	215°	2070
45.	67.	37.	3.5	6.0	65.	23.	220°	

value, taken in any given scale, of the generator E.M.F.; *ad* that of the motor E.M.F. as taken from the magnetization curve; *ac* that of the resultant E.M.F.; *ag* that of the main current. The angle *bad* measured backward (or clockwise) shows the phase position of the motor armature with respect to the generator armature, and it should substantially agree with the disc reading of the phase indicator.

The energy in watts delivered by the generator to the circuit is equal to the product of the impressed E.M.F. (E) and the component of the current *ag* in line with the impressed E M.F.

The energy transformed (H.P.) in watts by the armature is equal to the product of E' and the component of the current *ag* in line with E'. This product must be negative in value, showing energy consumed and not produced, for the machine to run as a motor.

The difference between the watts delivered and the watts transformed is equal to the C^2R losses of the armature circuit.

In practice the phase position of the current is sometimes in advance of the impressed E.M.F., as seen in Fig. 5 (*ag*), though it

may lag behind it. If it is in advance, the motor produces a capacity effect upon the circuit. If it lags, it produces the effect of self-induction upon the circuit. Its position is determined by the degree of field excitation and by the self-induction of the armature. For maximum efficiency and greatest out-put, it should evidently have exactly the phase position of the generator,

Below are tabulated the results of the graphical computations and a comparison of disc readings. The speed being very nearly constant during the run, we have taken ω as constant. With a constant self-induction we have, therefore, a constant value for the angle ϕ for the readings, viz., 82.5°. It will be seen from the table how nearly the computed values agree with the observed ones.

E Generator E.M.F.	E′ Motor, E.M.F.	E″ Resultant, E.M.F.	C′ Generator Field Cur'nt.	C″ Motor Field Current.	C‴ Main Current.	Disc Reading, Angle θ.	Computed Angle θ.	Watts Input.	Watts transformed into H.P.	C R Losses of Line and Motor Cir't in Watts.	Computed C·R Losses in Watts.
40.5	20.2	20.23	3.5	1.8	11.5	185°	180°	61	32	29	28.
40.5	22.7	18.04	"	2.	10.25	187°	188°	131	101	30	22.
41.5	25.	16.27	"	2.2	9.25	190°	193.5°	201	165	36	18.
41.5	27.4	14.59	"	2.4	8.3	190°	187.3°	126	104	22	14.4
41.5	29.7	13.45	"	2.6	7.65	190°	190.5°	160	148	12	12.3
42.	32.2	12.11	"	2.8	6.9	190°	191°	180	172	8	10.
42.	34.5	11.33	"	3.	6.4	195°	192.7°	206	197	9	8.6
42.5	35.7	10.63	"	3.2	6.05	193°	192°	197	196	1	7.7
42.5	39.25	10.9	"	3.4	6.2	198°	195°	250	240	10	8.1
43.	41.7	11.33	"	3.6	6.46	198°	195°	278	269	9	8.8
43.	44.	12.21	"	3.8	6.9	198°	195.5°	294	286	8	10.
43.	46.5	13.2	"	4.	7.51	200°	196.3°	312	302	10	11.8
44.	48.9	14.59	"	4.2	8.3	200°	197°	348	336	12	14.4
44.5	51.2	16.27	"	4.4	9.25	200°	198°	382	374	8	18.
44.5	53.7	18.13	"	4.6	10.3	200°	198.5°	401	376	25	22.4
44.	56.1	20.6	"	4.8	11.7	200°	199°	427	392	35	28.8
44.5	58.4	23.22	"	5.	13.2	200°	201.3°	496	455	41	36.6
45.	60.7	26.4	"	5.2	14.8	205°	203.5°	568	519	49	46.
45.	63.1	28.88	"	5.4	16.4	205°	204°	613	552	61	57.
45.	65.6	32.2	"	5.6	18.3	208°	206.5°	689	619	70	70.2
45.	68.	35.79	"	5.8	20.3	215°	208.5°	778	694	84	87.
45.	70.3	40.5	"	6.	23.	220°	212°	855	657	98	111.

TEST OF THE HAMILTON STREET RAILWAY PLANT.*

BY W. F. MC LAREN AND J. H. MEIKLE.

The test was made on Tuesday, the 27th of March, 1894, a run being made of 12 hours, from 8:30 a. m. to 8:30 p. m.

BOILER TEST.

The boilers tested were five fire tube boilers manufactured by the Goldie McCulloch Co. Ltd., of Galt, Ont., the dimensions of each being, diameter of shell, 60″, number of tubes, 74, diameter of tubes, 3″, length of tubes, 14′, grate area, 16□′.

Readings were taken every ten minutes of boiler pressure, room temperature, and feed water temperature, and readings for the determination of furnace temperature and flue temperature, at intervals of two hours. A throttling calorimeter was used, which was inserted in the steam pipes leading to engine No. 2, about 2′ from the main steam pipe. The method by which the feed water was measured is as follows: The two feed pumps, only one of which is generally used, were put in operation. One was employed to pump the water from the hot-well into a barrel through a nozzle: a pressure gauge being placed in the pipe just above the nozzle. The other pump was employed to pump from the barrel into the boilers. As there was considerable variation in the pressure, the pressure gauge was not read at regular intervals, but the time and pressure were noted at every change. The coal used was a mixture of about equal parts of Pittsburg Slack, and Scranton Screenings, a chemical analysis of which is given below:

ANALYSIS.

Kind of Coal.	*Scranton Screenings.*	*Pittsburg Slack.*
Moisture,	9.5 per cent.	4.1 per cent.
Volatile Matter,	6.3 "	40.4 "
Fixed Carbon,	75.5 "	42.2 "
Ash,	8.8 "	13.3 "

The averages of the different readings were used in obtaining the following results:

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* Abstract of thesis presented for the degree of M. E.

BOILER TEST.

Duration of Trial	hours	12
Grate Surface	sq. ft.	80
Pressure,		
Barometer	pounds	14.81
Steam Gauge	"	104.7
Absolute Steam Pressure	"	119.51
Temperature,		
Boiler Room	degrees F.	47
Flue	"	387
Furnace	"	1699
Feed Water	"	109.5
Steam (calorimeter)	"	251
Fuel,		
Total Coal Consumed	pounds	9349 S.S. 9794 P.S.
Moisture in Coal	per cent.	9.4 S.S. 4.1 P.S.
Dry Coal Consumed	pounds	17863
Total Refuse, dry	"	2810
Total Refuse, dry	per cent.	14.15
Total Combustible	pounds	15053
Fuel per hour,		
Dry Coal per hour	pounds	1488
Combustible per hour	"	1254
Dry Coal per sq. ft. of grate	"	18.6
Combustible per sq. ft. of grate	"	15.6
Quality of Steam	per cent.	97.57
Superheat in Calorimeter	degrees F.	38.5
Total Weight of Water Used	pounds	141533
Total Evaporated Dry Steam	"	138093
Factor of Evaporation		1.15
Total, from and at 212°	pounds	158807
Water per hour,		
Amount Used	pounds	11794
Evaporated Dry Steam	"	11508
Evaporated from and at 212°	"	13234
Per Pound of Fuel.		
Actual	pounds	7.39
Equivalent from and at 212°	"	8.29
Per Pound of Combustible.		
Evaporation,		
Actual	pounds	9.4
Equivalent from and at 212°	"	10.5
From 109.5° F. to 104.7 lbs. by Gauge.		
Per Pound of Fuel	pounds	7.21
Per Pound of Combustible	"	8.61
Per Sq. Ft. of Grate Per Hour.		
Actual	pounds	147.4
Equivalent from and at 212°	"	165.4

Horse Power (on basis of $34\frac{1}{2}$ pounds equivalent evaporation per hour)		383.6
Heat Generated per hour	B.T.U.	13522375
Heat Absorbed per hour	B.T.U.	12754039
Efficiency of Boiler	per cent.	94.3
Efficiency of Furnace		62.94
Weight of Water in Coal	pounds	1280
Weight of Carbon required to evap.	"	99.9
Weight of Coal required to evap.	"	171
Weight of Coal required to evap. per year of 312 days of 18 hrs. each	pounds	79028

ENGINE TEST.

The engines tested were three tandem compound, condensing engines, rated at 275 H. P. each, manufactured by the Goldie McCulloch Co. Indicator cards were taken every ten minutes from each cylinder, and amperes read as rapidly as possible while the cards were being taken. Speeds were taken during the first half of the run, simultaneously with the cards, but as they were found not to vary more than one revolution, it was thought unnecessary to continue these readings further. In computing the E H.P. we took averages of the several readings at the time the cards were taken.

The condenser on engine No. 3 was not in working order during the first three hours of the test. The exhaust valve on the low pressure cylinder of this engine was broken, allowing the steam to blow directly through so that no appreciable work was done at this end of the cylinder.

The results given below were computed from the averages of the different readings obtained during the run.

ENGINE TEST.

Duration of run	hours	12
Revolutions per min.		89
Diameter of Cylinders	inches	16 & 30
Length of Stroke	"	38
Diameter of Piston Rod	"	$3\frac{3}{16}$
Boiler Pressure	pounds	104.7
Barometer Pressure	"	14.81
Boiling Temp. Atmos. Press.	degrees	212.5
Total I.H.P.		482.6
Total E.H.P.		362.1
Total Water Used	pounds	141533
Total Water Used by Pumps and Condensers (computed)	"	9798
Total Water Used by Engines	"	131735
Water per I.H.P.	"	23.14
Water per E.H.P.	"	30.02
Coal per I.H.P.	"	3.13

Coal per E.H.P.	"	4.06
Combustible per I.H.P.	"	2.4
Combustible per E.H.P.	"	3.3
Steam wasted through broken valve	"	2999
Per Cent. of Steam wasted		2
Actual Steam Consumption per I.H.P.	pounds	22.68
Plant Efficiency E.H.P.÷I.H.P.	per cent.	75

CAR TEST.

The test was made on Monday, March 26th, the company allowing us a special car for the purpose. All the connections in the car are brought together under one of the seats, and at this point the instruments were attached. A 200-ampere shunt was connected in the main trolley circuit, and current read by means of a milli-voltmeter attached to its terminals. Two voltmeters were used, one being connected between the trolley and ground, and the other directly to the brushes of one of the motors. Readings were taken on these instruments every five seconds. The speed was determined by counting the poles passed in each ten seconds. The grades were obtained from the city engineer's office. The rails were dry and in good condition during the run.

The results of the test are shown in the accompanying table. Only those parts of the run where the most reliable readings were obtained are shown here, average volts and amperes being used in the computations. The armature resistance is .52 ohms. Knowing this, the drop in armature was calculated and the counter E.M.F. determined by subtracting the drop from the brush volts. The ratio of the counter E.M.F. to the brush volts gives the motor efficiency. The computation of traction effort is based on the assumption that a pull of 20 pounds per ton is required to keep the car moving at a uniform speed on a level; the necessary increase being added for grades. Let W=weight of passengers and car in tons, and p = per cent. of grade. Then

$$\text{traction effort} = W \times 20 + W \times 2000 \times \frac{p}{100} = W \times 20\,(1+p).$$

For starting torque we used 70 pounds per ton and we have for traction effort $= W(70 + 20\,p)$. We estimated the weight of car and passengers to be 5.6 tons. The H. P. expended $= \dfrac{\text{Traction Effort} \times \text{Speed in ft. per min.}}{33000}$. If the H. P. supplied be determined from the amperes and trolley volts, we get the car efficiency from the ratio of these two. The total torque on each armature is measured by half the traction effort multiplied by the radius of the armature in feet, the radius being .98 feet.

RESULTS OF CAR TEST.

STREETS.	Grade Per Cent.	Feet Per Min.	Miles Per Hour.	Average Current.	Trolley Volts.	H.P. Supplied.	Brush Volts.	Drop in Armature.	Counter E.M.F.	Traction Effort, Lbs.	H.P. Developed.	Torque Ft. Lbs.	Efficiencies.	
													Car.	Motor.
Emerald to Wellington on King . .	2.	1400	15.9	38.4	437.5	22.5	407.5	10.0	397.5	336.0	14.25	164.5	63.4	90.8
McNab to Bay on King	.6	1100	12.5	44.2	427.2	25.3	391.1	11.5	379.6	179.2	5.97	87.8	23.6	88.8
Bay to Caroline on King	.8	1100	12.5	41.0	415.0	22.8	375.0	10.6	364.3	201.6	6.71	98.8	29.4	87.9
Caroline to Queen on King	2.7	1100	12.5	52.8	403.9	28.5	357.3	13.7	343.6	414.4	13.78	203.0	48.3	85.1
Queen to Pearl on King	1.3	900	10.2	53.6	418.0	30.0	373.0	13.9	359.1	257.6	7.02	126.0	23.4	96.3
Oak to Hannah on Locke	1.3	1000	11.4	54.8	409.8	30.1	352.8	14.2	338.6	257.6	7.80	126.2	25.9	82.7
Caroline to McNab on Herkimer .	1.	1300	14.8	40.2	429.7	23.1	393.3	13.5	379.8	224.0	8.82	109.7	38.1	96.5

Average Car Efficiency 36 per cent. Line, 80 per cent.
Average Plant Efficiency (from coal to generators) 6.83 per cent.
Total Efficiency of System 1.95 per cent.

STARTS.

STREET.	Grade Per Cent.	Maximum Current.	Trolley Volts.	H.P. Supplied.	Traction Effort.	Torque.
Ferguson on King	2	77	420	43.3	616	302
James and King	.6	77	445	46.5	459.2	225
Main and Margaret	0	83	425	47.3	392	192
Main and Locke	0	103	405	56.0	392	192
Herkimer and Locke	0	117	410	64.3	392	192
Queen and Herkimer	1	137	400	73.5	504	247
King and James	0	77	442	45.6	392	192

TEST OF THE MOTORS OF AN ELECTRIC STREET CAR.*

BY EUGENE B. CLARK AND QUINCY A. SCOTT.

There have been so many thorough tests of electric street car motors that the writers feel some hesitation in offering anything further upon this subject. However, no attempt will be made to go into detail as to the method of testing or the results obtained; but there will be given simply an outline of one or two of the most prominent points.

The testing of electric motors *on the car* involves many difficulties, even under the most advantageous conditions. We will assume that the conditions are favorable, *i. e.*, that the car is entirely at the disposal of the testers and that a skilled motorman is at the controller, and then go on to point out the obstacles. The greatest objection, if the road is at all uneven, as nearly all roads are, and the readings are taken at regular intervals, is that a large number of observations will be taken when the car is going down hill, and a large number more when the car is slowing down or speeding up. Now those taken on the down grade will generally become apparent upon an examination of the results, a profile map having been used to indicate the position of the car at each reading, so that these need cause no trouble. Not so, however, with those taken when the speed is changing. If the car is speeding up it is gaining momentum, and consequently the electrical supply must furnish power to communicate kinetic energy to the moving mass as well as to propel it at the speed at which it is traveling at that instant. If we define the operating efficiency as the ratio of the power represented by the moving car (obtaining from the known weight, speed, traction coefficient, and grade) to the power supplied from the line, we will see that this efficiency will not be a true one if the kinetic energy is changing. If the car is slowing down it will be running partly on its own momentum, and the mass will be giving up its kinetic energy. The operating efficiency in this case will be false also.

The only way to obviate this difficulty is to have a continuous speed record in order to know at just what readings the car is moving at a constant rate. In the test referred to in this abstract the Boyer Railway Speed Recorder was geared onto the car axle,

* Abstract of thesis presented for the degree of M. E.

similarly to the manner in which it is used on locomotives. This instrument gives a continuous autographic speed diagram in which the abscissæ represent distances traveled, in miles, and the ordinates represent the speeds, in miles per hour, at each instant. By the use of this machine the tester is enabled to tell whether or not the car is changing speed at the time of the reading. (This process is an easy and accurate one. Lack of space prevents its elucidation here.)

Other difficulties that are likely to be responsible for the introduction of errors into the results are the facts that the motorman may have the motors in series when the observer supposes them to be in parallel, and that he may have his brakes on when the observer thinks he has not. The tester cannot insure against these possibilities. All he can do is to keep an eye on the motorman, and take his chances as to the result.

In computing the power represented by the motion of the car, it is customary among electrical engineers to assume that the traction coefficient (the force required to pull a known mass at a constant speed along a level track) is constant at all speeds, 20 lbs. per ton being a fair value under average conditions. It is evident, however, that this is not strictly true, for this force is expended in overcoming rolling and axle friction and air resistance, which do not remain constant at varying speeds. The journal friction varies approximately as the square of the speed and the air resistance approximately as the cube of the speed. It is probably safe to assume, however, that, at the low speeds common to electric cars, the traction coefficient is practically constant. At least this is the best we can do until we get some more accurate knowledge as to the variation of the traction coefficient at different speeds, on different grades, and under different condiditions of track. We know that in using the figure for traction coefficient that has been stated—20 lbs. per ton—we fall into an error which may be more or less serious according to the prevailing conditions, and this very fact impairs to quite an appreciable extent the value of a car test.

The writers believe that by the use of the autographic speed record the speed problem has been overcome and that it is necessary now only to determine definite values for the traction coefficient to place all car tests on an equal basis.

TEST OF AN OTTO GAS ENGINE.*

BY W. F. HUNT AND W. J. ANDREWS.

This thesis shows so high thermal and mechanical efficiencies that it has been deemed advantageous to describe the engines and the results.

Engine No. 1. (12 H.P. Nominal) which had just been assembled, used the regular Otto cycle which is as follows:

1st. Charge of air and gas drawn into the cylinder. 2nd. Compression (to about 65 lbs.) 3rd. Explosion and expansion. 4th. Discharge of products of combustion.

When a revolution is to be made without an explosion the governor causes the gas valve to remain closed, the partial vacuum formed by the forward movement of the piston opens the air valve, and a charge of air is drawn into and discharged from the cylinder at approximately atmospheric pressure.

Poppet valves were used and the gas and exhaust valves were controlled by the governor. The air valve was actuated by the atmospheric pressure.

Engine No. 2, (6 H.P. Nominal) worked through a slightly different cycle, viz.: instead of drawing in and discharging air when a cycle was passed through without explosion, a portion of the burned charge was retained and alternately compressed and expanded until the engine was about to take a new charge, when the governor acted and opened the exhaust valve at the head end of the cylinder. In moving forward, the piston uncovered, near the end of its stroke, an exhaust valve through which was discharged that portion of the burned gas which was not to be compressed on the return stroke.

The cycle thus becomes: 1st. The charge of air and gas drawn into the cylinder. 2nd. Compression (to about 80 lbs). 3rd. Explosion, expansion and partial discharge. 4th. Either complete discharge or compression of the remaining portion of the burned charge as determined by the action of the governor.

The partial vacuum, formed when about to take a charge, by the forward movement of the piston opens the air valve, which transmits its movement through a lever to the gas valve and opens it.

There is a valve on the top of and opening into the cylinder,

* Abstract of thesis presented for the degree of M. E.

consisting of a chamber of adjustible length containing a small metallic ball which fits into seats at each end of the chamber. The ball, when acted upon by the pressure, moves up and down with the backward and forward movement of the piston, allowing a leakage, and makes the starting of the engine less laborious.

When starting the engine the charge is fired later than when up to speed.

The arrangement for testing both engines was identical. Thermometers were placed so as to obtain the temperatures of the entering gas, the entering and leaving jacket water, and the exhausted gas.

The jacket water was collected and weighed by means of an iron tank placed on a pair of sçales. Connections were so arranged that the jacket water could be run into the tank, or into an overflow pipe as was desired, since the tank was not large enough in some tests, to contain the total water for a complete run.

Continuous counters were connected so as to record explosions and revolutions. Thompson Indicators were used, which had been made especially for the high temperatures and pressures developed in these engines. They differ in construction from the ordinary Thompson Indicator in having longer piston rods and a piston area of only ¼ square inch. The Indicator used on Engine No. 1, had a spring of 122.4 lbs, per inch; that used on Engine No. 2, 162.54 lbs. per inch. These results are from calibrations made in the Laboratory of Sibley College.

A wheel reducing motion had to be employed, as the inertia of others tried was so great as to rupture them.

An investigation of the effect of the inertia of this reducing motion was made by obtaining the length of the movement of the indicator drum when the engine was turned over by hand and when running at full speed.

Assuming the inertia effect to be the same on each side of the middle position of the indicator drum, as seems to be the case, the length of a card was divided into twenty equal parts and accurate measurements made of the heights of the expansion and compression lines at each of these points. These heights were laid off upon the length which the card would have had if there had been no inertia at points corresponding to those on the first card. A card was then drawn which was thought to represent the form of a card having no inertia. The area of each of these cards divided by its length was so nearly the same that the difference was inappreciable. And so it was concluded that the inertia effect did not alter the mean effective pressure.

The gas meter used was calibrated, three determinations showing the meter to read 3.75% too small.

In test No. 2 the temperature of the exhaust ran so high that it was necessary to resort to a calorimetric method. The gas used was West Philadelphia gas and had a B.T.U. value of 710. per cubic foot at 32° F. and atmospheric pressure. In calculating the temperature of the explosion the formula $\frac{pv}{T}=\frac{p'v'}{T'}$ was used. The ratio of air to gas is known and the amount of gas per explosion is found by dividing the total gas used by the total explosions. Now, the volume of the cylinder is filled by this air and gas at practically atmospheric pressure, so its temperature can be calculated. Therefore, having this, we have $\frac{pv}{T}=\frac{p'v'}{T'}$, in which everything is known except T', which can be calculated. And by this formula the temperature at different points of the cards can be found.

By this method the following temperatures were obtained. At compression 800.° F. absolute, maximum temperature of explosion 3590.° F. absolute, and at point of exhaust 2130.° F. absolute. This was from engine No. 2.

Those from engine No. 1 were about the same except in the case of the exhaust, which was about 200° F. higher.

DIMENSIONS ENGINES.

	No. 1.	No. 2.
Diameter of Piston, . . .	6.75″	5.75″
Length of Stroke, ...	1.2916 ft.	1.041 ft.
Clearance % vol., ...	34.95	25.63

The following table gives the principle results :

No. of Engine.	No. of Test.	R. P. M.	Explosions per Min.	I. H. P.	D. H. P.	Cu. ft. Gas per I. H. P.	Cu. ft. Gas pr D. H. P.	B. T. U. per I. H. P.	Mechanical Effic.	Thermal Efficiency.	Temp. of Ex'st, °F.	Per Cent. Heat Distribution. Friction Loss.	Jacket Loss.	Exhaust Loss.	D. H. P.	Unaccounted for.
1	1	245	73	9.	7.03	18.125	23.2	12358	.781	.205	718	.0451	.3425	.3385	.1606	.1133
1	2	246	120	15.35	12.9	17.825	20.43	12150	.842	.209	946	.0331	.336	.1635	.1762	.2912
2	3	305	143	9.38	8.38	19.78	22.14	13460	.893	.189	697	.0202	.3371	.1247	.16875	.3493
2	4	265	123	8.50	7.66	18.4	20.42	12460	.901	.204	633	.02014	.3868	.1104	.1838	.29886
2	5	312	153	10.12	9.08	19.235	21.416	13040	.897	.1951	710	.02	.3125	.126	.175	.3665
2	6	305	15.2	1.09	0	18.36	. . .	12350	. . .	.206	218	.2061	.371	.0284	. . .	.3945
2	7	307	78.2	5.31	4.28	19.89	24.68	13410	.807	.18925	482	.0355	.431	.07485	.15235	.3061
2	8	304	86.8	5.98	4.83	18.525	22.95	12555	.808	.2025	524	.039	.318	.0838	.1635	.2957

This table indicates that while engine No. 1 shows a smaller gas consumption per I.H.P. than engine No. 2, the percentage of work done for energy supplied, which is the total efficiency, shows engine No. 2 to be doing slightly better work, notwithstanding its smaller size. These engines were new commercial engines and had just been assembled.

INDUCTION MOTORS.*

BY M. H. GERRY, JR.

The induction motor to-day is a commercial success. Its development in the last eight years marks an epoch in the history of the electrical industry. For simplicity, efficiency, ease of control, and general adaptability to all conditions, it is in advance of all other apparatus for the distribution of power. The synchronous alternating motor, developed simultaneously, has, perhaps, certain advantages over the induction type for the transmission of power to distant points in large units, and where it can be utilized at a constant speed. In most cases, however, power is utilized finally in driving individual machines in comparatively small rather than in large units. One of the great problems, then, in this field of engineering, is the distribution to single machines and small consumers of the power generated at central stations or transmitted over trunk lines from a distance to a central distributing point. To solve this latter problem the induction motor has been developed to its present degree of perfection.

Motors of this type are *par excellence* for simplicity. They consist essentially of two laminated iron structures, the primary and secondary, the one revolving and the other stationary, and each provided with a simple winding. The primary, if stationary, receives the polyphase currents directly in its windings without commutator or sliding contacts, while the secondary winding is closed on itself directly or through a resistance carried on the armature shaft and without external electrical connections. The parts subject to mechanical wear in such a motor are reduced to a minimum, being simply the journals of the machine.

The starting and running torque of motors belonging to this class has been the subject of much discussion, but it is now well understood that this is a simple point of design; that is, an induction motor may be constructed and adjusted to give any desired torque curve. In fact, induction motors possess advantages in this particular over direct current shunt motors, and there seems to be no especial difficulty in equalling the best series motors in this respect. Working well within the limits of saturation for the iron, the torque of the motor depends directly on the strength of the magnetic field, and the current in the secondary winding.

* Abstract from a thesis presented for the degree of M. M. E.

The strength of the magnetic field is due to the primary magnetizing current, and depends, therefore, on the rate of change of the E. M. F. impressed by the line on the terminals of the primary winding. The torque of the motor can therefore be varied by changing the resistance in the secondary circuit and thus varying the current in that element. In this case the magnetic field remains unaltered.

The torque may also be varied by means of resistance in the primary circuit, but in such a case additional resistance reduces the effective E.M.F. impressed on the terminals of the motor and consequently the magnetic field. Hence with the same current through the motor in this latter case, the torque will be less and the motor efficiency proportionately reduced. This is brought out very clearly by curves obtained experimentally by Dr. Louis Bell and published in a recent paper before the American Institute of Electrical Engineers.* The desirable way to regulate the torque of induction motors is, therefore, to introduce resistance into the secondary circuit, and this can be done very simply, and will regulate successfully over wide limits. The speed of the motor is independent of the torque, and depends directly on the resistance of the secondary. By a proper adjustment of this secondary resistance, the desired torque can be obtained at any speed. For such purposes as hoisting and traction it is desirable to have maximum torque at starting, while for most power purposes, constant speed with a maximum torque at, say 50 per cent. overload and at nearly the running speed is required. Either of these and all intermediate conditions can be met by an adjustment of the resistance as outlined above. In some recent torque and speed curves published by Mr. Steinmetz† for a 100 H.P. motor, the drop in speed is only about 3 per cent. from no load to full load, and a maximum torque of not far from twice the running torgue is obtained at about 10 per cent. reduction in speed. Another curve shows the same motor adjusted to give its maximum torque at starting and then decreasing at a uniform rate up to the synchronous speed.

The power factor is another subject in connection with induction motors which has received much attention. The power factor is that quantity which multiplied into the apparent watts gives the true watts delivered to the motor, or in other words, it is the cosine of the angle of lag of the current behind the im-

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* Transactions A. I. E. E.. Vol. XI, No. 2.

† Transactions A. I. E. E.. Vol. XI, No. 3.

pressed E.M.F. With high power factors the idle current on the line is small, thus reducing the ohmic loss from this source, and the reactance of the circuit being less, there is no serious drop in the potential such as would result with low power factors. High power factors are desirable, then, first on the score of actual reduction of the ohmic loss in the line, and secondly as securing the better regulation at the generator. It was formerly supposed that induction motors necessarily gave low power factors, but such is not the case, as much recently published data from such machines shows full load power factors in the vicinity of 90 per cent, aud half load factors of 85 per cent. This, of course, means an increase of from 10 to 15 per cent. in the ohmic loss of the line and a somewhat larger exciting current for the generator. On the other hand this additional ohmic loss is seen to be a per cent. of a per cent. of the total power and not so serious as might at first appear. And further the reduction of pressure is such as can be easily taken care of by modern alternating generators.

Still better, perhaps, is the use of condensers to increase the power factor. By this means a power factor of nearly unity may be obtained, and the writer believes that with the general introduction of induction motors the condenser will come very largely into use. The action of the condenser is of course well understood, it simply producing a capacity current 180° from the self-induction current, the two neutralizing each other when properly adjusted, and leaving only the work current on the line. The conclusions reached at this point are then, that power factors can be obtained of values such as not to seriously interfere with the successful operation of systems employing this type of motors, and further that by the use of condensers any desired results can be secured in this particular.

Leaving, then, the practical considerations of torque, speed and power factor, we come to the mooted question of the variation of the rotary magnetic field. The writer has devoted no little time and study to this interesting subject, and the conclusions arrived at are that under all circumstances of actual motor construction such variations do exist, but in many recent types of apparatus they are so small as to be negligible. On the other hand, it is very easy to produce a design that will give anything but a uniform field and may even reverse direction or produce dead and lock points. In discussing this subject it may be well to state, first, that a rotating field may vary in one or both of two ways : the total number of lines per pole may change, or the total num-

ber be constant and their distribution over the area may vary. An absolutely constant rotating field in both these respects would be such a one as results when a permanent bar magnet is revolved about an axis at right angles to a line adjoining its poles, and in a homogeneous magnetic medium, as air. Such a field as this is not approximately produced in induction motors, although the first condition is nearly satisfied in several types. The total number of lines may be very nearly the same per pole at all instants of time, but the distribution over the polar surface be constantly changing from a peaked to a flat topped form, and vice versa. With certain arrangements of the windings there is a third kind of variation of field, or perhaps more properly it may be looked upon as a special case of the second class of field fluctuations named above.

Let us consider, first, a two-phase field where there are but two conductors per pole, one for each phase. For this case there are two extreme conditions of field, one when the currents are equal to each other, and a second condition, when one of the currents is zero and the other a maximum. The first of these gives the flat topped distribution of lines over the polar area, and the second the peaked form. The total magnetization per pole for this arrangement will vary four times per period from values represented approximately by 1 to 1.4.* For a three-phase field having one conductor per phase and per pole, the flat topped distribution is obtained when one of the currents is zero, and the peaked distribution at the instant when one of the current is maximum. In this case the total magnetization per pole varies six times per period from a value represented approximately by 3.9 to a value of 4. The maximum flux is obtained when the distribution is of the peaked form, while in the former case it obtains when the distribution is flat topped. The actual amount of variation is here so small that it may be neglected, being far less than would result from a slight inequality or shifting in phase of one of the currents. By increasing the number of conductors per phase, provided they are distributed uniformly in separate grooves, over the primary surface, the distribution and total magnetic flux may be varied. For two-phase winding, taking all things into consideration, from 2 to 4 conductors per phase per pole would seem to give the best distribution, and for three-

* For the diagrams developing this and the following cases see thesis M. H. G. Jr.

phase construction, from 1 to 6 conductors; it being understood that each conductor represents an armature or field lug.

As the number of conductors per phase and per pole is increased, each conductor being in a separate groove, there is introduced a variation of magnetic intensity at different points on the primary circumference, and that, if carried to an extreme, may give rise, when the motor is running near synchronism, to fluctuations in the primary current, with resulting harmonics. It may be well to state here that it is immaterial as far as the magnetic distribution is concerned, how many turns there are per groove, the only factors entering the problem being the number and dimensions of grooves and lugs per phase and per pole, and the ampere turns in each groove. If the primary of the motor be constructed with actual "poles" in form similar to the field of a multipolar generator the treatment is the same, for example a two-pole two-phase motor of this description might have four material "poles," but it is essentially a field having one lug per phase per pole with all of the conductors belonging to a phase in a single groove. Motors of this description with primary lug surfaces of considerable dimensions are subject to armature reaction and bunching of the induction on one side of the surface. This can be corrected to a considerable extent by using a pole-face winding or similar device.

Let us consider next a case where there are six conductors and lugs per phase per pole for a three phase motor. The peaked form is obtained here as before when one of the currents is maximum while the flat topped distribution is produced at the instant when one current has zero value. The peaked distribution gives the greater flux in the ratio of 31 to 25. The variation is seen to be greater than was the case with one conductor per phase per pole, and there are also additional variations of maximum induction along the surface of the primary.

Through the lugs between the different systems of conductors the magnetization has maximum variation of intensity, while through lugs in the center of a system of conductors it is least. With the construction just indicated it may vary 20% between these points on the circumference. There will be, therefore, fluctuation of E.M.F. in the secondary, due to the movement of conductors, which has no relation to the actual volocity of the rotating field itself. The periodicity of these fluctuations will increase as the motor approaches synchronism, while the periodicity of the fundamental secondary induced E.M.F. de-

creases. At synchronous speed the fundamental secondary E.M.F. will have no value, while the periodicity and pressure of these superinduced E.M.F.'s will be maximum. These variations in the secondary E.M.F. give rise to variations of secondary current, and these in turn to variations of the primary current. At first sight there might seem to be danger from this cause of producing higher harmonics of considerable value in the primary. However, if we consider that the periodicity of these superimposed fluctuations is, in every case, very low compared with the impressed E.M.F., we see that while they may form harmonics with the secondary E.M.F., the periodicity of which depends on the motor slip and is consequently low, in no case are they likely to give trouble on the line. In any event, if in the future trouble is experienced from this cause, it is easy to avoid such fluctuations by proper design.

Still another subject in connection with induction motors is that of the periodicity of the impressed E.M.F. At present the weight of evidence seems to show that it makes very little difference as far as induction motors are concerned what periodicity is used if the motors are designed with this in view. Below is given a table of number of poles and synchronous speed for different periodicities.

No. of Poles.	Velocity in revolutions per minute.		
	At 25 periods.	At 50 periods.	At 130 periods.
4	750	1500	3900
8	375	750	1950
12	250	500	1300
20	150	300	750

The number of poles in this class of machinery is not so important a matter, excepting in small motors, as in other electrical machinery, where the structural difficulties are sometimes considerable. In fact, it seems better to the writer to increase the number of poles on all large machines of this type, as a more even magnetic distribution and slower speed is obtained, at the expense, however, of a somewhat more bulky construction.

The weight of induction motors is about the same as that of other motors for the same speed and conditions. I quote from Dr. Louis Bell* the weights of a number of machines per horse power, giving also the figures from well known lines of direct current motors, for the purposes of comparison.

* Transactions A. I. E. E., Vol. XI, No. 2.

H. P.	Weight in lbs. per H. P. Induction Motors.	Direct Current Motors.
5	103	135—110
10	66	130— 90
15	68	120— 65
20	73 (6 pole)	110— 60
100	66 [8 pole)	105— 55

We see from this table that there is but little difference in the matter of weight per H.P., and considerable improvement could doubtless be made in this particular if it were desirable to design with this especially in view.

The design of induction motors is in some respects simpler than that of direct current motors. The methods in use in the design of transformers apply with slight modifications to motors of this type. In fact, an induction motor is in reality but a special type of transformer with one of the elements so arranged as to be free to move, or at most it is a combination of transformer and motor. Looking at the subject in this light, and by applying the ordinary formulæ, etc., of transforming practice, the writer has arranged a method of design in his thesis which is believed will give a ready solution of the more important problems arising in designing mechinery of this type.

The induction motor is destined to play an important part in the future development of the manufacturing as well as the electrical industries. Cost of power is an important item in the production of all manufactured goods. Power can be generated most cheaply by water or steam in large units, and in such cases the efficiency of transmission to the point of utilization is at least as important as the efficiency of the prime movers. An efficiency of 90% can be attained with motors of this type, and after allowing for generator and line loss the efficiency of transmission for full load can be maintained as high as 80%. All-day efficiency of motors, under varying loads, of from 50 to 60% can be attained, as compared with 20% and under, for all-day efficiency of shafting, belting, rope-transmissions, etc., as ordinarily used in mill work. Induction motors are, then, especially adapted to the transmission and *distribution* of power at distances up to ten miles, and perhaps to many times that amount.

INVESTIGATION OF AN EDISON GENERAL ELECTRIC NO. 10 STREET CAR MOTOR.*

BY I. E. MACOMBER.

Although this Thesis has for its main object the efficiency test of a motor, it may, in a sense, be considered as illustrating a *method* of motor testing, which, while not new, differs in many respects from the ones in common use. Not only is it possible by this method, which is perfectly general, to test the efficiency of a motor in a simple and accurate way, but data are obtained which clearly exhibit the losses in the machine; the method is therefore one of more than usual value. Consider for a moment the lines of reasoning along which this method, as applied to the test of a constant potential series motor, has been developed.

Evidently, the torque produced by a given current flowing through a motor can be experimentally determined. As the motor is designed for a constant potential circuit, knowing the current in the machine, the counter-electro-motive force can be calculated. The product of the counter-electro-motive force and the current gives, the wire losses only being considered, the power developed at the pulley of the motor. From the power developed and the torque, the particular speed at which the motor will work becomes known. Therefore, if at this particular speed and field excitation, the losses of the motor can be determined, the power, which must be supplied the machine that it may develop the *calculated* power at the pulley, is found. The efficiency follows at once. The test of a motor by this method may be resolved then into two parts:—A practical investigation of the losses in the motor under various conditions. A consideration of torque as related to current and speed.

The method of testing a constant potential series car motor may be explained more in detail as follows:

Find, by the fall of potential method, the resistance R_a of the armature and brushes, and the resistance R_s of the fields. Let the motor be run under no load.

Separately excite the fields at constant voltages, between the limits of the lowest and highest possible values.

For each *constant* field, separately excite the armature, varying the power supplied and noting the changes of speed.

From the data thus obtained, plot curves of speed and volts

*An abstract of a thesis presented for the degree of M. E.

supplied the armature, and speed and watts supplied the armature, for *each constant field excitation.*

From these primary speed curves determine the number of watts which must be supplied the armature, and the electro-motive force which must be impressed upon it, at *various* field excitations, in order that the speed may be maintained constant. Now the loss in a motor may be divided into wire loss, iron loss, and friction loss. Of these, the wire loss will depend upon the current flowing, the friction loss may be considered constant for a given speed, and the iron loss will vary as the speed and armature induction, but may be considered constant for a given speed and armature induction.

The power supplied the armature, at a given strength of field, that it may maintain a constant speed, must be entirely wasted, since no useful work is performed, and must equal the sum of the friction, wire, Foucault current, and hysteresis losses, in the armature for that speed. At the given strength of the field, and constant speed therefore, the watts and impressed electro-motive force in the armature, necessary to maintain the speed are known; the current, C_a is known; the resistance R_a of the armature is known; the $C_a^2 R_a$ loss therefore is known.

By subtracting this wire loss from the power supplied to the armature, a result is obtained which must equal the number of watts, at the given speed and strength of field, wasted in hysteresis, Foucault currents, and friction. Thus, the losses in hysteresis, Foucault currents, and friction *for a constant speed*, at *various* strengths of field, may be determined.

From this derived data a constant speed curve may be plotted with volts in the armature as ordinates, and hysteresis, Foucault currents, and friction loss in the armature as abscissæ. Evidently this curue prolonged will cut the X-axis at a point whose distance from the Y-axis is an exact measure of the turning friction at that speed; for at that point the voltage in the armature is zero and therefore the loss in hysteresis and Foucault currents is zero. A set of constant speed curves covering a large range of speeds will give data for a friction curve in which speeds are plotted as ordinates and friction losses as abscissæ.

Now, the counter electro-motive force in the armature, divided by the speed, is always proportional to armature induction β. For convenience let

$$\frac{e}{r} = \beta'$$

where e = electro-motive force and r = revolutions per minute. Evidently $e = E - C_a R_a$, when E is the potential of the circuit upon which the motor is working.

It is now readily seen that from the set of constant speed curves just explained, a second set may be plotted in which, at constant speeds, hysteresis, Foucault currents, and friction losses are plotted as ordinates and corresponding β' as abscissæ.

It now becomes necessary to know the amount of torque produced by a definite current flowing through the motor. That is, a curve of torque and current must be plotted with pounds torque at one foot radius as ordinates, and amperes of current in the motor producing the torque as abscissæ. To obtain this data, an arm of known length, the end of which rests upon a pair of scales, should be rigidly fastened to the pulley of the motor. A suitable correction being made for the weight of the arm itself, the pounds of torque at one foot radius produced by a definite current through the motor, is easily observed. One of the most important curves in the test of the motor is the curve of speed and torque, as from it a knowledge of the speed at which the motor will work can be obtained.

Let, as before, E be the constant potential of the circuit upon which the motor is working, and assume the current C_a flowing through the motor. From the curve of torque and current, the torque T for C_a can be easily obtained. Then

$$e = E - C_a (R_a + R_s)$$

and $\frac{e\,C_a}{746}$ = H.P. developed by the motor, wire loss only being considered. Also $\frac{2\,\pi\,T\,r}{33000}$ = H.P. developed by the motor.

Therefore,

$$\frac{2\,\pi\,T\,r}{33000} = \frac{e\,C_a}{746}$$

whence

$$r = \frac{33000}{2\,\pi\,746}\,\frac{e\,C_a}{T}$$

$$= \frac{(7.061)\,e\,C_a}{T}.$$

Assuming different currents to flow through the motor, the data for the curve is obtained. If it were not for the friction and iron losses, the motor

Efficiency would equal $\frac{e}{E}$.

Therefore, for each load on the motor these losses must be found before the true efficiency can be computed.

As has just been explained, for a given current C_a flowing through the motor, the torque T, counter electro-motive force e, and therefore the delivered power at the pulley are known. Now,

$$\frac{e}{r} = \beta'$$

Knowing the speed r, and β', from the second set of constant speed curves, the loss, in hysteresis, Foucault currnts, and friction can be found; call this loss l. The efficiency equals then

$$\frac{e\,C_a}{e\,C_a + l}$$

Curves of horse power and efficiency and curves of speed and efficiency can readily be plotted.

SOME RESULTS FROM EXPERIMENTS WITH A DIRECT CURRENT SHUNT MOTOR ADAPTED TO TRI-PHASE SYNCHRONOUS WORKING.*

BY CLINTON KIMBALL.

The four-pole machine under consideration was designed for a generator output of 40 amperes at 100 volts with 1200 revolutions per minute. A thorough direct-current motor efficiency test was made, and then, with thirty to forty hours work and the expenditure of a few dollars for materials, a tri phase synchronous motor was produced. It should be stated that the number of sections in the armature winding was not divisible by three, and that, although connections were made to commutator-bars as nearly as possible 120° apart, yet as a result eleven separate coils were between two of the collector-rings, and only nine in each of the other two circuits of this triangular connection. The tri-phase current was from a remodelled 10 H. P. Sprague motor having 30 commutator-bars and hence producing a symmetrical, though "flat-topped" wave of current at 21 p.p.s.

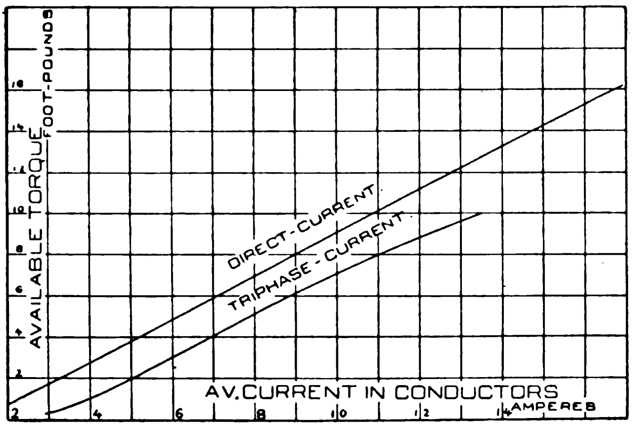
*An abstract of thesis:—"The Direct-Current Shunt Motor as a Tri-phase Machine," presented by Clinton Kimball for the degree of M. M. E. Full details of the design of this machine as a direct-current dynamo may be found in an article by Professor H. J. Ryan, "On a Method of Balancing Armature Reactions," in THE SIBLEY JOURNAL for October, 1892.

It was found that an average current of 25 amperes in each of the lines would run the machine—belted to a direct-current dynamo, running "light"—up to a speed closely approaching synchronism. This was a result of the inductive action of eddy currents in the solid pole-faces. The pole-face winding was short circuited in another set of trials but no beneficial result could be discovered. When the motor was noticed to have attained its maximum speed under these conditions, the exciting current was turned into the field coils and then the motor could be said to "*jump*" into synchronism, at a normal speed of 630 r. p. m. As a result of this action a most striking decrease of the amperemeter reading was observed, for the current in one of the lines dropped from 25 to 5 amperes, thus showing a five-fold increase of the power-factor.

The adjoining table is a summary from the efficiency test of the tri phase synchronous machine.

Rev. per Min.	Av. alt. volts impressed between terminals.	Sum of three Alt. Currents.	Sum of Observed Watts.	Exciting Current.		Tot. Input.	Available Output.	Available Torque.	Per cent. Effic.
				Amps.	Watts	Watts	Watts	Ft. lbs	
637	13	14½	78	2.23	192	270	0	0	0
638	14½	28½	180	2.40	221	401	. . .	. . .	. . .
629	15	29	235	2.42	225	460	119	1.36	25.9
630	14½	35½	366	2.30	204	570	240	2.68	42.1
634	15	39½	447	2.30	204	651	310	3.44	47.6
637	13	35½	496	2.50	240	736	379	4.18	51.5
637	15	40½	588	2.59	258	846	496	5.48	58.6
635	15	46½	670	2.58	257	927	592	6.57	63.9
624	15½	55	805	2.50	240	1045	705	7.95	67.5
620	17	75	915	2.40	221	1136	792	9.00	69.7
635	17	67	996	2.40	221	1217	891	9.87	73.3

A casual inspection will show that the machine could have been run at two or even three times the speed, with a higher periodicity, and so the output increased in like ratio. This would effect the relation between input and output of the armature very



Curves of Torque.

little, but it is easily seen that the percentage reduction for total efficiency would not be nearly so great, for the 220 watts, more or less, for exciting the field would now represent a much smaller part of the total input of the machine.

One of the most interesting features of the results, as worked up, is shown by the accompanying curves of torque for equal currents, direct and alternating, in the armature conductors. The field excitation was practically the same, but the speed, in the case of direct-current running, was almost twice that in tri-phase working. In the first case, one-half of the observed direct-current in the armature, was the current flowing in any one conductor. In tri-phase working with the balanced triangular connection and sine wave of current the flow in any one of the circuits in the triangle is accurately .578 of the current in one of the lines. With the tri-phase conditions at hand, we have an unbalanced circuit and flat-topped waves of current. The rule adopted was, that the average current in one conductor equals .6 of ⅓ the sum of the observed values of the currents in the three outside lines.

The output of the motor was obtained by belting it to a separately excited direct-current generator, whose friction and iron losses had been previously determined.

In measuring the input by a Weston watt-meter, several difficulties arising from this unbalanced and triangular or mesh connection of the armature had to be overcome. The object in view

was the measurment of power transmitted over each of the three lines. It was a simple matter to arrange a device fór throwing the current of any one of the lines through the current coil of the watt meter, but quite another to submit the pressure coil to the voltage of the same line, as no neutral point exists in the mesh as in the star connection. It seemed reasonable to suppose that a neutral point could be obtained if three *equal* high resistances were placed in star connection between the three leads. Accordingly, three 100 volt incandescent lamps of very nearly equal resistance, were placed in star-connection and the pressure coil of the watt-meter connected between this center or neutral point (marked o in Figs. 1 and 2). and the line wire, whose current was passing through the current coil.

No attempt has been made to prove the accuracy of the method by analytical means, but the two tests to be immediately reviewed will perhaps remove doubt as to its reliability for the work in hand. Let us denote the line wires by the numbers 1, 2 and 3 respectively.

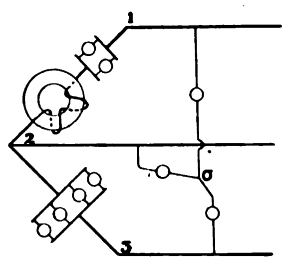


FIG. 1.

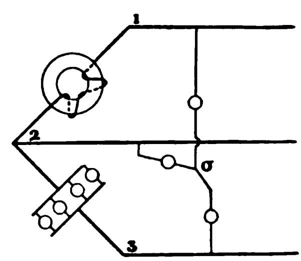


FIG. 2.

Test No. 1.(See Fig. 1)—The secondary of an open-circuited transformer was placed in series with two parallel connected 50 volt, 16 c. p. lamps, between 1 and 2; and 2 and 3 were joined through 4 parallel-connected 50 volt lamps. No direct connection was made between 3 and 1. As observed by the above method, the watts for 1, 2 and 3 were respectively 39, 125 and 84; sum, 248. Then the power expended in 1–2 was measured in the regular manner as with single phase circuits and its value found to be 75, and 2–3 by this method showed an expenditure of 180 watts. This summed gives 225 watts. Comparing this with the former result we have an agreement as close as could be expected, for the walt-meter could not be read closer than 2 or 3 watts and it is not absolutely certain that a slight variation of E.M.F. had not occurred between the two sets of readings.

Test No. 2. (See Fig. 2)—The circuits were the same as the former, with the exception of the connection between 1 and 2, which in this case consisted of the secondary of the open-circuited transformer, alone. The readings—using the neutral point for 1, 2 and 3 were −110, +242, +39 respectively, with an algebraic sum of 171. Then, by the ordinary method, 1—2 and 2—3 showed a respective expenditure of 102 and 66 watts, making a total of 168 watts.

From these results it seems that for measuring power in an *inaccessible* mesh-connection of the tri-phase circuit this method is reliable.

THE ELEMENTS OF TIME AND TEMPERATURE IN CYLINDER CONDENSATION.*

BY S. HENRY BARRACLOUGH, B.E.

The history of the steam engine may be said to be, in large part, the history of cylinder condensation, since the process of evolution in the engine, both as regards its mechanism and its conditions of operation has been to a very great extent influenced and directed by the consideration of the thermal loss due to the action of the cylinder walls. To it are due to a greater or less extent, compounding, superheating, steam jacketing, variations in proportions of cylinder, increase in speed, and modifications of working conditions generally.

The three important sources of loss in an engine are the thermodynamic, the thermal, and the frictional. The principles affecting the first of these have been thoroughly developed by the labors of Rankine and Clausius, to whom is due the honor of practically

*An abstract of portions of a thesis presented for the degree of M.M.E.

NOTE. In the preceding issue of THE SIBLEY JOURNAL is an article on a somewhat similar subject by Mr. L. S. Marks entitled "An Analytical Study of the Initial Condensation in Steam Engines." There is of course a good deal in common between the subjects of that article and the present one, but the object kept in view in writing the latter was to include as far as possible only such portions of the subject as were not treated in the former, or which differed from it in the method of treatment. The two articles will perhaps be of more interest as illustrating the different results arrived at by two writers who both started from the same foundation of experimental data and attempted to ascertain the laws governing a particular series of phenomena.

producing a new science. The loss due to friction may also be said to be known for all practical purposes, but the laws governing the thermal loss, or what is commonly known as the loss due to cylinder condensation, are still undetermined except in the most indefinite way. As the magnitude of this latter is usually a large percentage of the total loss it is evident that a true theory of the steam engine is impossible until such time as these laws are fully developed.

The conditions which are usually assumed to be the most potent in affecting the amount of initial condensation are :—(a) Area and condition of surface exposed to the incoming steam, (b) Proportions of cylinder, (c) Revolutions per unit time, (d) Steam pressures and corresponding temperature range, (e) Ratio of expansion, (f) Quality of steam, (g) Several special expedients arbitrarily applied—Steam jacketing, superheating, compounding, and certain others.

It may safely be said that no two writers on the subject are agreed as to the exact effect which each of these conditions has on the amount of initial condensation. Many formulae have been proposed by investigators along this line of research to represent the results of their experiments and the laws governing cylinder condensation which they have deduced. In nearly every case, however, it will be found that the equation is appliable only to the conditions under which the particular tests were made and does not represent the results of other tests nor does it correspond in form with any other equation proposed. It seemed to the writer that the reason for this might be found by supposing that the *function* representing the relation between cylinder condensation and any one working condition, such as speed, was not constant in form, but might vary when some of the other conditions were changed. That is to say, not only would the amount of initial condensation be changed by altering, say, the ratio of expansion, but the *law* connecting speed of rotation with condensation might also change with the alteration of ratio of expansion.

The probable reason why the laws of cylinder condensation have not been developed in accordance with this idea, is that there are few, if any, series of trials in which the conditions were varied sufficiently to allow of its being done.

The three requirements which, in the writer's opinion, a series of trials should fulfill, are : (a) Not only should each condition of working be varied, but each *set* of conditions should also be

varied. (b) There should be at least four, and if possible, more points on each curve showing the relation between the amount of condensation and any one of the working conditions. (c) The range in the magnitude of each working condition should be as large as practicable. The work of several investigators complies very satisfactorily with the latter requirements, but Willans' series of tests are the only ones available which even approximately fulfil the first of them, and this is counterbalanced by there being in many of his series only three points on a curve. It is very evident of course, that to carry out a series of experiments which would comply with these requirements would require a large expenditure of time and labor. As an example, suppose it is undertaken to ascertain what effect the three conditions of pressure, speed, and ratio of expansion have on the amount of initial condensation. If it be assumed that five points are necessary to fix each curve, it will at once be seen that to vary each set of conditions when three conditions are involved would require 125 different tests.

It was hoped that the series of trials undertaken by Mr. Marks and the writer would have included these three conditions, but as the time available was not sufficient for the purpose it was decided to only include the elements of speed and pressure. The method employed in these experiments was to fix upon some steam pressure, and, while keeping it and all other conditions as constant as possible, to make a series of tests at speeds varying from 85 to 25 r. p. m.; then to pass to some other steam pressure and make a second series of runs at the same speeds as before, and so on. The speeds chosen were 85, 70, 55, 40, and 25 r. p. m. and the absolute admission pressures 120, 100, 80, and 60 lbs. per sq. in. respectively.

Before taking up the consideration of the effect of changing the speed and pressure on the amount of initial condensation, it will be of interest to see how such change affects the economy of the engine as represented by its steam consumption. The result of the entire series of trials was to give an excellent confirmation of the so called "Willans' law" of total steam consumption, which states that the total steam used by an engine per hour is directly proportional to the horse power developed. In the original statement of this fact by Willans it was meant to apply only to those cases where the horse power was varied by altering the initial pressure, but the present series shows it is to be equally true when the horse power is varied by altering the number of revolutions per minute. It was further found that the diagram water rates or

the amount of steam used per hour as accounted for by the indicator cards also followed the same law, and as the amount of steam condensed per hour is the difference between the actual and indicated consumption, it at once follows that the amount of steam condensed per hour is directly proportional to the horse power developed.

The element of time in cylinder condensation will now be considered. It is first necessary to take some quantity as the unit of condensation, and for this purpose either the percentage, the amount per minute, or the amount per revolution may be chosen. The percentage condensed although practically useful is not a suitable unit for discussion from a scientific standpoint, and of the other two it is immaterial which is taken, since one is immediately convertible into the other. For convenience, the amount of steam condensed per minute will be chosen as the basis of the present discussion. It would be more accurate to consider the number of heat units given up to the walls rather than the amount of steam condensed by the walls, but the latter way is more common and the error so introduced is not large.

It can be easily shown that theoretically

$$Q = \frac{K}{N^{\frac{1}{2}}}$$

where Q is the heat loss to the walls per stroke, N is the number of revolutions, and K is a constant. Taking this expression as a model, many formulae have been constructed to represent the loss by initial condensation with varying speeds, the values of the constant and of the index of N being changed to suit the circumstances of different experiments. These different expressions do not agree among themselves, however, and no single one of them represents even with a fair degree of accuracy all the available data. Considering the fact that in a real engine the theoretical conditions are never complied with, and often not even approximated to, it would seem wiser to plot the two quantities under discussion and then to assume the form of equation which best represented the resulting curve, rather than to attempt to force the results to comply with the theoretical form of the equation. The equation should of course, be one which fairly represents all the available data and not merely the results of some one particular set of tests.

In the accompanying series of curves (fig 1,) are coördinated the weight of steam condensed per minute and the corresponding

number of revolutions per minute for each of the present set of trials. It will at once be seen how very closely straight line curves represent the points ; it is indeed doubtful whether any

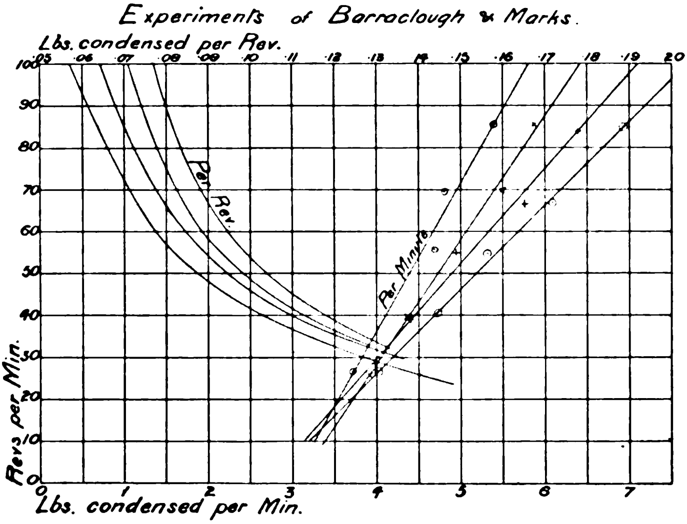


Fig. 1.

other form of curve that could be drawn in would give so close an approximation, and as, *ceteris paribus*, a straight line curve offers great advantages, on the score of simplicity, it will be assumed for our purposes that the equation connecting condensation per minute with revolutions per minute is of the form

$$N = m A + C.$$

Having obtained the curves for condensation per minute, those for condensation per revolution can be at once determined by taking a series of points on each of these straight lines and dividing the abscissa of each point (lbs. condensed per minute) by its corresponding ordinate (revs. per minute) and plotting this quantity as a new abscissa, the ordinate remaining the same as before. It is evident of course, from the method of obtaining them, that these new curves will be hyperlolas.

Leaving for a time the consideration of the element of speed in cylinder condensation, some attention will be given to that of temperature. Practically, nothing definite is at present known regarding the temperature cycle of the metal walls of a cylinder. A good deal of experimental work has been done on the subject

but the results so for have not been conclusive. It is usually assumed, for the want of anything better, that the amount of initial condensation will bear some relation to the termperature range of the steam, either from admission to release or from admission to exhaust. Any such assumption as this is to be regarded as merely conventional, however. since it can be shown that there is no simple relation between the temperature cycles of the walls and steam. It will be seen, nevertheless, from the accompanying

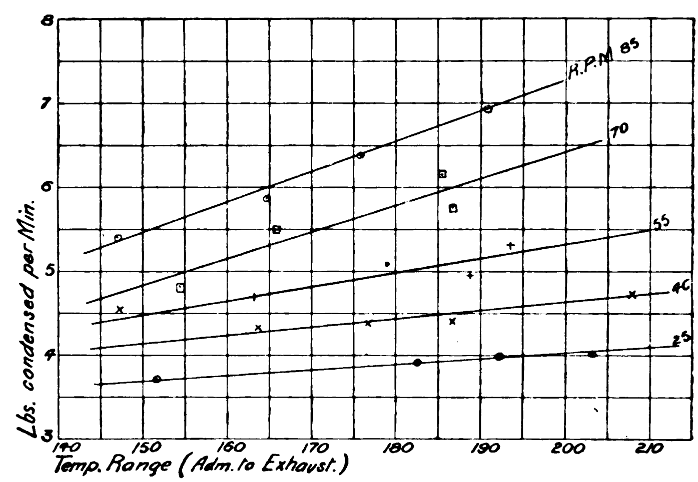


Fig 2.

curves (fig. 2,) that for practical purposes the assumption is a very fair one, since straight lines can be drawn which represent very approximately the positions of the various points. These straight line curves can be represented by equations of the form

$$A = K(T - t) + b$$

where A is the amount of steam condensed per minute and $T - t$ the temperature range.

We have now found the form of equation that represents the variation of condensation with change of speed at any particular pressure, and with change of pressure at any particular speed, and it only remains to consider the method to be employed in obtaining an expression which shall represent the amount of steam condensed when both the speed and pressure vary. The argument heretofore generally adopted in deducing such an expression may be stated somewhat as follows: Since the variation in the

amount of condensation, when coördinated with speed and with temperature range, can be represented by straight line curves, it may be assumed that condensation varies directly as the speed and as the temperature range, and hence when both these quantities vary the condensation will vary as their product, or in symbols:

$$A \text{ varies as } N(T-t)$$
$$= KN(T-t)$$

The fallacy in this argument lies in the fact that it neglects the constants in the equations of the straight line curves. For instance, returning to the equation giving condensation with changing speed,

$$N = mA + C$$

it is evident that there will be a certain amount of condensation even when N is zero, which would not be the case if the condensation varied directly as the speed. Furthermore, although "m" and "C" are constants for any particular pressure and temperature range, the positions of the curves in Fig. 1 show that they vary when the pressure varies. In other words, "m" and "C" are not constants, but are *functions* of the temperature range, and if these functions can be determined and substituted for "m" and "C" in the above equation, the result will be an expression representing the amount of condensation per minute when both the speed and pressure, or temperature range are altered.

The numerical values for the equations to the four straight lines are, respectively:

$$N = 38.5\,A - 120$$
$$N = 30.0\,A - 91$$
$$N = 22.4\,A - 60$$
$$N = 20.0\,A - 54$$

Now by coördinating these numerical values of "m" and "C" with the mean temperature range (fig. 3), a form of function can be obtained between the temperature range and "m" and "C."

The curves were found to approximate closely to hyperbolas, and the following numerical values were obtained when the temperature range was assumed to be from admission to exhaust.

For "m" $$m = \frac{1350}{232 - (T-t)}.$$

For "C" $$C = -\frac{3600}{227-(T-t)}.$$

Substituting the expressions in the equation

$$N = mA + C$$

we have

$$N = A\frac{1350}{232-(T-t)} - \frac{3600}{227-(T-t)}$$

or

$$A = \left(N + \frac{3600}{227-(T-t)}\right)\frac{232-(T-t)}{1350}$$

This then is the final expression for the amount of cylinder condensation when both speed and pressure, or temperature range are varied. This series of tests was made with a ratio of expansion of about 3. If the series could be extended so as to include tests made at various ratios of expansion it would probably be

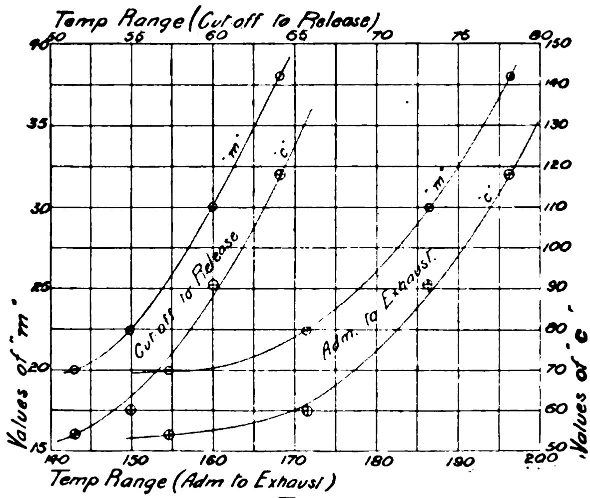


Fig. 3.

found that the numerical "constants" in this final equation are not in reality constants, but are functions of the ratio of expansion, and consequently the equation could be advanced a step further so as to give the amount of condensation when the three conditions of speed, pressure, and ratio of expansion were all varied.

Indeed, provided the experimental data were sufficient, this

process could be carried on until all the variable conditions had been included in the equation, and any constants then appearing in it would be merely numerical and not dependent on the circumstances of the case.

Space does not allow of any account being given of the comparisons which were made between the various foregoing equations and the results of the tests of other investigators. This is of small moment, however, as the object of this article is not so much to actually produce an expression which shall include all the available experimental data, a thing which is indeed at present impossible, but rather to illustrate what is, in the writer's opinion, the best method of setting about the achievement of this feat.

THE EFFECTS OF PERIODICITY ON THE ARC LAMP.*

BY RALPH NORTON FLINT.

The considerable range of periodicities through which modern alternate current machinery is operated, and the constant tendency towards larger machines and generally lower periodicities, has called for experiments to investigate the effects of periodicity on the arc lamp, and to determine the limits of periodicities at which they will operate successfully.

Among the phenomena which might be expected to depend to some extent on the periodicity are: the noise, the current flowing with constant E. M. F., the carbon consumption under same conditions, and the regulation. The noise may be expected to decrease, in pitch at least, with the periodicity.

From the equation for current in alternating circuits, which is $C = E.M.F. \div Imp.$, where $Imp. = \sqrt{R^2 + \omega^2 L^2}$, $L =$ coefficient of self induction and $\omega = 2\pi \times$ periodicity, we would expect to find the current increasing as periodicity decreased.

The carbon consumption, however, may be expected to vary with the current and in about the same manner. The regulation would vary, if at all, in a way not easily foretold.

We would also expect to find some phenomena, such as flickering, at the lower periodicities, which would fix the lower limit at which the lamp could be used.

In this investigation the effect of periodicity on each of these

* An abstract of a thesis presented for the degree of M. E.

phenomena was, as far as possible, observed. The speed was varied by means of a pair of cone pulleys.

The average values of observations taken during runs of two hours each are here shown.

P. P. S.	I.	I_2.	E. M. F.	R. P. M.	Carbon cons. per hour, (grms.)
143.3	24.62	11.06	30.40	2150	7.80
		10.91	30.		7.70
123.	25.32	11.95	30.33	1845	7.59
		11.82	30.		7.51
100.	24.63	12.08	30.	1504	8.02
89.	24.98	12.43	30.67	1335	8.15
		12.16	30.		7.97

The current and carbon consumption are shown as observed, and also as reduced to equivalent values when the E M.F. is thirty volts. Plotting values of P.P.S. and I_2 we have a smooth curve. In plotting P.P.S. and carbon consumption only one point did not fall on a smooth curve. In each case we find the values increasing as periodicity decreases. The current I_2 increases 1.25 amperes or 11.4 per cent. throughout the range of periodicities.

In the above runs power was measured by the three ammeter method, substituting, however, voltmeter readings and known resistance for the ammeter readings in the non-inductive branch. The values obtained in these measurements are here shown.

P.P.S.	EMF.	R.	I.	I_1.	I_2.	W_2.	$E\times I_2$.	Dif.	θ.
143.3	30.4	2.19	24.62	13.88	11.06	318.78	336.22	17.44	18° 32′
123.	30.33	2.20	25 32	13.78	11.95	339.13	362.48	23.35	20° 40′
100.	30.	2.18	24.63	13.76	12.08	296.18	362.40	66.22	35° 11′
89.	30.67	2.20	24.98	13.94	12.43	302.45	381.19	78.74	37° 30′

In the above $W_2 = \frac{1}{2}\left(R\,I^2 - R\,I_1^2 - \frac{E^2}{R}\right)$

$I_1 = E \div R.$ $\cos.\,\theta = W \div (E \times I_2).$

$\theta =$ angle of lag.

It is seen that the angle of lag, and also the difference between the power measured by this method and the apparent watts, each increase as the periodicity decreases. This is probably a result not looked for. From the above equation for current flow we

should expect to find θ decreasing with the periodicity, providing self-induction was the only quantity affected. It would seem then that there is some other phenomena varying with the periodicity, and to a much greater extent and in an opposite direction from the variation of the self-induction. This phenomena probably is the counter E.M.F. of the arc. Assuming it as established that there is such a counter E.M.F.* and that it is due to electrolitic action, we should expect to find its direction reversed with each reversal of the current. We may also expect that with high frequencies, this counter E.M.F. will not have time to reach its final maximum value before its direction will be reversed, while as the periodicity decreased it would have time to reach more nearly its maximum value. This counter E.M.F., then, would be quite small at the higher periodicities, and would increase as the periodicity decreased, approaching a final maximum value, which would be the counter E.M.F. of a direct current arc lamp. Such a counter E.M.F. probably would account for the observed phenomena.

The dynamo used would not furnish the power necessary for three ammeter measurements at a lower speed than the above, so in the following runs this method was abandoned.

The average values of six other runs is here shown.

Observed.					Computed.		
P. P. S.	Curr.	E.	P. P. M.	Cons.	E.	Cur.	Cons.
149.3	11.185	31.46	2240	7.48	30	10.67	7.13
105.	11.42	30.12	1577	7.93	30	11.37	7.90
84.	11.48	30.17	1260	8.33	30	11.42	8.28
75.	11.64	30.25	1127	8.40	30	11.54	8.33
63.	11.74	30.3	947	8.00	30	11.62	7.92
56.5	11.88	29.35	848	7.92	30	12.14	8.09

These values of current and carbon consumption when plotted as ordinates, with periodicity as abscissae, form quite smooth curves, showing that the current and carbon consumption each increase as the periodicity decreases. The increase of current in the above range of periodicity is 1.47 amperes, or 13.78 per cent. which corresponds very well with the first series of runs when the greater range of periodicity is considered.

Additional runs were made, but in them the current and E.M.F.

* For a discussion of the Counter Electromotive Force of the Voltaic Arc, see a paper by F. J. Rogers in the *Proceedings of the Electrical Society of Cornell University* for '93-'94, Andrus & Church, publishers, Ithaca, N. Y.

could not be kept at their former values. The observed values were as follows:

R. P. M.	P. P. S.	Cur.	E. M. F.
742	49.5	9.4	30
690	46.	8.8	28
630	42.	9.	31.5
583	39.	9.	25.
548	36.5	9.	17.

The current and E.M.F. readings in these low periodicity runs are liable to be somewhat in error, but the results are useful in showing the performance of the lamp at the low periodicities.

We have, then, worked through a range of frequency of from 150 to 36 periods per second. The noise decreased both in pitch and loudness with each decrease of the periodicity. At 150 periods per second it was so loud as probably to prohibit the use of the lamp in all places except, perhaps, street lighting. At about 50 periods per second the noise was not objectionable, at 40 periods per second it was practically inaudible, while at 36 periods per second no noise could be heard. Flickering began to be perceptible at 39 periods per second, and increased rapidly. Also, this phenomena was observed to be much greater with a short than with a long arc.

The lamp was observed to regulate much better at low than at high periodicities, other things being equal.

In the measurement of power by the three ammeter method, I was measured by a Thompson balance, and I_2 by a Siemen's dynamometer. These instruments were compared with each other at periodicities varying from 60 to 150 periods per second. If we assume the balance as the standard and read the current from the calibration curve taken at 100 periods per second, then the current, as shown by the dynamometer, is about four per cent. too low at a periodicity of 150 per second, and four per cent. too high at 50 per second.

The arc lamp used was designed for parallel working. Three determinations of mean spherical candle power were made. The averages of these values were,

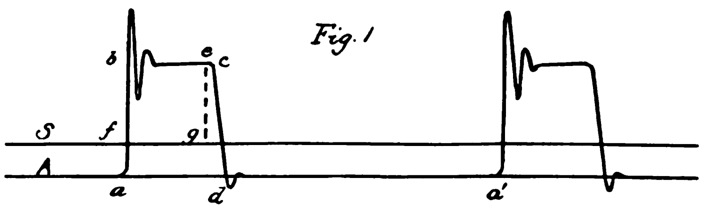
Mean spherical candle power = 174,
Mean candle power at 45° = 288,
Mean horizontal candle power = 115.

INDICATOR CARDS FROM AN HYDRAULIC RAM.*

BY C. E. HOUGHTON.

A steam engine indicator was connected to the supply or drive pipe of an ordinary hydraulic ram close to the air chamber. The drum of the indicator was removed and the cards (Figs. 1 and 2) were drawn on a large drum, which was revolved at a uniform rate by means of a small motor. The action of the ram may be traced from these cards as follows:

During the time the waste valve is open, the indicator pencil follows the atmospheric line. As the velocity of flow increases, the valve suddenly closes as at (a) and the pressure rises very quickly to the pressure in the air chamber or to a little above, and the valve in the air chamber is opened. (The vibrations shown in Fig. 1 are doubtless caused by the inertia of the indicator).



S = static pressure line. A = atmospheric line.

While the valve in the air chamber remains open the pressure is the same in the pipe and chamber. This valve closes at some point c and the pressure falls rapidly to that of the atmosphere or a little below, causing the waste valve to open and a new stroke to begin.

The time of one complete stroke is represented by the distance $a\ a^1$. Knowing the number of strokes per minute we thus have a measure of time.

The cards are time-pressure diagrams, and since $p\ t = m\ v$, the area of one is proportional to the total work done on the water during one of the strokes. This work is both positive and negative. The positive work is that done by the kinetic energy of the moving water, and is equal to the useful work plus the lost work.

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* Abstacted from a thesis presented for the degree of M. M. E.

The negative work is that done on the water in the supply pipes after the kinetic energy of the water is exhausted.

This work is equal to the potential energy of the water that flows from the air chamber to the supply pipes before the valve between them is closed, plus the work required to raise the pressure in the supply pipe to that in the air chamber. This latter quantity is probably very small in most cases. It is evident that if we knew the velocity of flow at the time the waste valve closes we could calculate the efficiency of the ram from the relations of the area of the cards, proportional to the total and useful work. The writer had not been able as yet to measure the velocity, but has calculated it approximately as follows:

In a given case the useful work done was raising 56 pounds of water 30.55 ft. in 7 minutes ram working at 66 strokes per minute.

The work done per stroke was

$$\frac{56 \times 30.55}{7 \times 66} = 3.7 \text{ foot pounds.}$$

The efficiency of ram and connections was

$$\frac{g\,h_1}{Q\,h} = \frac{56 \times 30.55}{200 \times 12.75} = 67\%.$$

If we assume a loss of 20% in the ram then

$$\frac{m\,v^2}{2} = \frac{3.7}{.80}, \text{ or } v^2 = 3.36 \text{ and } v = 1.83 \text{ ft.}$$

Using this value of v and solving for the head lost by friction in the supply pipe, using 0.03 as the value of f we have the lost head (Merriman)

$$h'' = f\,\frac{l}{d}\,\frac{v^2}{2g} = 1.25 \text{ ft.}$$

Adding to this the head lost by friction in the elbows, which according to Weisbach equals about 0.6 ft., and subtracting the sum from the original head, we have as the effective head, $12.75 - 1.85 = 10.9$. Using this value for the head we have the efficiency of the ram $= 79\%$. This agrees fairly well with the assumption made to determine the velocity.

Having found a value of v we will now calculate the efficiency from the cards. Those given in Fig. 1 are for the above given case.

The total area above the static pressure line is .48 □ in.

Solving the equation $Pt = mv$ we find as the value of t, be, and the area proportional to the positive work in $begf = .41 \square$ in. The negative work is then proportional to $.48 - .41 = .07 \square$ in. and since an amount of positive work equal to the negative work must be done the useful work is $.41 - .07 = .34 \square$ in.

The efficiency is the relation of the useful work to the total positive work and is $\frac{.34}{.41} = 83$ per cent.

This would seem to indicate a small error in the assumptions made in determining the velocity but it will show how the cards may be used.

Until some means of measuring the velocity is discovered, the efficiency cannot be calculated from the cards. As graphical diagrams of the action of a ram the cards are interesting and useful. Leakage of the valves and the presence of any air in the supply pipe is shown very plainly by the shape of the card.

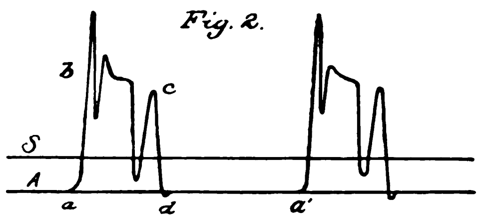
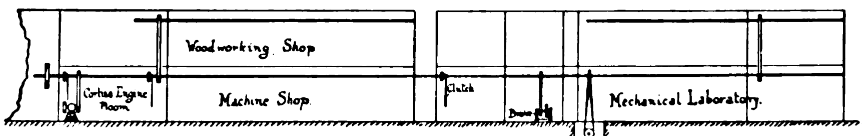


Fig. 2 is a card taken from the same ram under the same conditions. Some air had collected in one or more of the numerous elbows in the supply pipe and caused the extra vibration. This is a very bad case but the writer has found many times that the indicator gave a similar card, when in the working of the ram there was nothing else to indicate any adverse conditions, except perhaps a lower efficiency than should be expected.

EXPERIMENTS TO DETERMINE THE POWER ABSORBED BY SHAFTING, WHEN TRANSMITTING VARYING LOADS.

BY LIONEL S. MARKS, B.SC., AND S. HENRY BARRACLOUGH, B.E.

The object of the experiments described herewith was to determine whether the power absorbed by a line of shafting varies with the power transmitted, and if so, what is the law of such variation, and incidentally also to ascertain the average power absorbed by each bearing supporting the shaft. The experiments were carried out on the line of shafting which runs through the Sibley College machine shops and laboratories. The arrangement of the shafting is shown in the accompanying sketch.



Arrangement of Shafting in Sibley College Shops and Laboratories.

The main line, 300 feet long, and varying from $2\frac{15}{16}''$ to $2\frac{5}{16}''$ in diameter, is continuous throughout the whole length of the shops and laboratories, and has two clutches by means of which either the laboratory or both the shops and laboratory can be thrown out. From this main line power is transmitted by belting to the shafting in the wood working shops, the mechanician's rooms and to the shaft in the tunnel connecting the laboratory with the blacksmith shops. The number of hangers supporting the shaft, and the number of loose pulleys driven by it during the test, are given in the following table :

Room.	No. of Hangers.	No. of Loose Pulleys.
Corliss Engine Room, ...	8	0
Machine Shop, ...	24	72
Woodworking Shop, ...	13	19
Ground Floor of Laboratory, ...	19	1
Mechanician's Room, ...	11	5
Tunnel, ...	12	0

The shafting is normally driven by the turbines in the gorge, but for the purposes of the test it was disconnected from the

cable-pulley shaft and was belted to the 8″x12″ straight line engine.

The power transmitted through the shafting was varied by belting from a large wooden pulley in the laboratory to another pulley on a countershaft, on which was also mounted a brake wheel.

The order of the experiments was as follows: The engine was first run unloaded and indicator cards were taken to determine its friction. It was then belted to the main shafting and drove only that portion in the Corliss Engine room, cards being again taken. Then the clutch was thrown in and the power required to drive the shafting of the shops was obtained. The clutch connecting with the laboratory was then thrown in and indicator cards taken, giving the work done in driving the whole of the shafting. From these experiments the power absorbed by the shafting in the Corliss Engine room, the shops, and the laboratories, could be separately obtained. The brake wheel was then connected to the main shaft and was made to absorb different observed powers, corresponding indicator cards being taken. The difference between the horse-power delivered at the brake and that indicated at the engine, minus the engine friction, is the power required to drive the shafting.

The result of the experiments are given in the following table:

Conditions of Test.	Total H.P. from cards.	H.P. deliv'd at brake.
MAY 21ST.		
Engine unloaded, ...	3.65	
Engine driving shafting in Corliss engine room only, ...	4.4	
Engine driving shafting in Corliss engine room and shops, .	10.82	
Engine driving all shafting, . .	15.22	
MAY 24TH.		
Engine driving shafting in Corliss engine room and shops, .	10.51	
Engine driving all shafting, . .	14.76	
Eng. driv'g all shaft. and brake,	19.88	3.45
" " " " "	20.96	4.17
" " " " "	25.24	7.08
" " " " "	27.8	8.69

From the above table we get:

Power absorbed by shafting in Corliss Engine Room 0.75 H. P.

" " " " in Shops . . . . 6.42 H. P.

" " " " in Laboratory { May 24, 4.40 H. P. / May 1st, 4.25 H. P. }

This power is absorbed in friction at the bearings and in driving loose pulleys. In the Corliss Engine Room the shaft drives no loose pulleys, so that the average power absorbed in friction at each bearing is .094 H. P. In the laboratory there are 42 bearings and 6 loose pulleys. If the power absorbed by the loose pulleys were neglected the average frictional loss at each bearing would be .101 to .105 H. P. and taking account of the loose pulleys the value .094 H. P., found in the Corliss Engine Room for the average friction of bearings, must be very nearly correct for the laboratory. Assuming this same value of frictional loss to hold in the shops, the 37 bearings there will absorb 3.48 H. P. leaving 2.94 H. P. to be distributed among the 91 loose pulleys, or an average of .0323 H. P. per loose pulley.

Another way of obtaining the quantities required, from the data, is as follows: If x is the average power absorbed per bearing and y the power per loose pulley.

$$37x + 91y = 6.42,$$
$$42x + 6y = 4.32,$$
$$\text{whence } x = .098 \text{ H. P.}$$
$$\text{and } y = .034 \text{ H. P.}$$

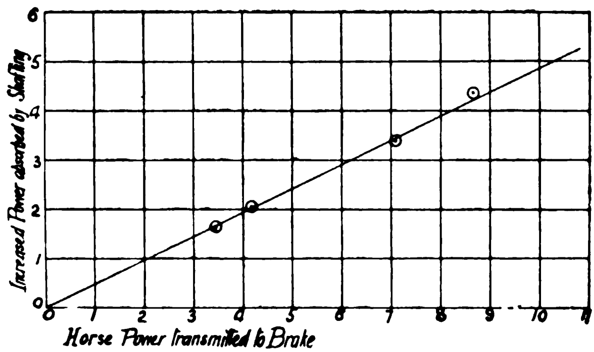
The average power absorbed by the bearings is thus seen to be practically the same as that obtained for the Corliss Engine room.

It may then be concluded that the average power absorbed in friction at each of the bearings is about $\frac{1}{10}$ H. P. and that the work done in driving a loose pulley is about one-third of that quantity or $\frac{1}{30}$ H. P.

The difference between the power required to drive all the shafting with brake attached and that required to drive it empty would be equal to the power delivered by the brake, if the power transmitted does not affect the friction of the shafting. The data obtained were:

Difference of power given to Shaft, loaded and empty.	Brake load.	Extra Power absorbed by Shafting.
5.12 H. P.	3.45 H. P.	1.67 H. P.
6.20 "	4.17 "	2.03 "
10.48 "	7.08 "	3.40 "
13.04 "	8.69 "	4.35 "

From this table it is seen that the extra power required is much greater than that delivered by the brake. Plotting the increase in power absorbed by the shafting, against the power transmitted to the brake, a straight line curve is obtained passing through the zero of ordinates; that is, the increase in power absorbed is



directly proportional to the power transmitted to the brake. The very surprising fact is also developed that the extra power absorbed is practically one-half of that transmitted, or in other words, one-third of the power put into the shafting, in excess of that necessary to drive it unloaded, is absorbed in increased frictional wastes. This may be expressed by the equation

$$F = C + \tfrac{1}{2} W.$$

Where F is the power absorbed by the shafting
C is the power required to drive it empty,
and W is the power transmitted.

—Among the numerous "Commencement" programs flooding the mails at the moment, we observe one from Bryn Mawr, where twenty-two young women take the degree of A.B., nine that of A.M., and one that of Ph.D. We notice one pleasant feature of the program which might well be imitated elsewhere: the candidates are introduced, group by group, by members of the faculty. This custom was introduced in a limited way at Cornell by President Adams, but has apparently lapsed. It is always pleasant to see the faculty given place on the program. It is they who make the university, and command distinction for it; they cannot be given preëminent place too generally or too scrupulously.

WORK IN FREEHAND DRAWING.

The course of instruction in freehand drawing, which precedes the work in mechanical drawing, in Sibley College, brings to light the otherwise unsuspected talent of a great many students. The most artistic work is usually done in connection with the advanced work of the students in architecture; but the second term of the first year is devoted to sketching from life, and from objects selected with some reference to the intended professional work of the student; and this, in the case of the mechanical engineers, regular or electrical, leads to the study of machinery, which is sketched in shops or laboratories. Many of these sketches are well worthy of preservation. Thus, we have in the accompanying illustration (see Frontispice) an example of good work by Mr. Mudge, of '97;—a dynamo drawn by hand and without the use of even a ruler or dividers, and after but a few weeks instruction. It is not to be claimed that an artist of long experience and of already acquired reputation might not criticise this drawing and himself do better; but we think it highly creditable to the novice who drew it and to his instructors, and a good example of the work of the beginner in Sibley College.

BOOK NOTICES

Proceedings of the Electrical Society of Cornell University. Published by Andrus & Church, Ithaca, N. Y., 1894. Price 50 cents.

This book is an octavo of nearly one hundred large pages. It begins with a list of officers, members, committees, the constitution, and an introduction, and then devotes the greater part of its space to ten papers selected from those that were presented before the society up to the time of the publication of the Prodeedings. The contents are:

Lead Secondary Batteries, C. P. Matthews; The Counter Electromotive Force of the Voltaic Arc, F. J. Rogers; The Design and Construction of Power Stations, Harris J. Ryan; Power Station Switchboards, F. R. Slater; Feeder Systems, D. A. Mason and O. P. Cummings; The Devopment of the Incandescent Lamp, E. L. Nichols; High Speed Electric Railroading, W. R. Turnbull; Notes on Some of the Work of Nikola Tesla, Eugene B. Clark; The Tesla High Frequency Phenomena, R. W. Quick; Long Distance Transmission of Power, James Lyman.

The papers are all of a high order, showing careful preparation; and the book is well edited. On the whole it reflects great credit on the committee, and on the society, especially since this is the first year of its existence.

Johnson's Cyclopedia, Volume IV., is just issued from the Press and is fully up to standard in its completeness and beauty of type, engraving and press work. It contains a considerable amount of matter from Cornell professors and lecturers:—Professor Bailey contributes his part in horticulture and general agriculture and its sciences; Professor Burdick, now at Columbia, writes some important articles in the department of law and jurisprudence; Professor Hutton, non-resident lecturer, writes of hot-air and gas-engines; President Jordan is the author and compiler of a number of articles in natural history; Admiral Luce writes of naval matters; Professor Nichols has long contributions upon electrical physics and related subjects; although his great work was seen principally in volume III. Professor C. H. Thurber writes some interesting biographies and pedagogical articles; Professor Thurston writes the articles on various kinds of machinery; Professor Wheeler makes extensive philological contributions, and Professors H. S. Williams and H. H. Wing add their valuable articles to the list, in their special fields. The scientific and engineering literature of the cyclopedia is particularly well prepared, and its writers include, among others already mentioned as contributors, such men as the late President Barnard of Columbia; Wm. P. Blake of New Haven; Professors Chandler and L. M. Haupt; Captain Ingalls; Professor Jacobus; Mr. C. H Kirschoff; Professors Merriman and Newcomb; Peck and Remsen; General Newton, and Major Powell of the Geological Survey.

Ex-president Adams is Editor-in-Chief, and Professors Nichols, Thurston, and Wheeler are on the staff of Associate Editors.

The Board of Editors for 1894–5 is as follows:

LOUIS B. HOWELL,,	*Editor-in-Chief.*
FREDERICK H. THATCHER,	*Business Manager.*
JOHN R. WOODBRIDGE,	'95.
CHARLES E. BARRY,	'96.
ARTHUR E. REINKE,	'96.

The Graduate Editor is to be elected in the fall.

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WITH this, the closing number of Volume VIII, the present Board of Editors resign the positions that they have filled for a year, to their successors. It is with mingled feelings of regret and relief that they give up their task ; for though it has sometimes been necessary to crowd other duties a little to find time for the work, nevertheless they feel that the time has been most pleasurably and profitably spent. In fulfiling their editorial duties it has been their aim to place before the readers of the JOURNAL subject matter that will be of more than passing interest. They have recognized the fact that the material so presented may have been of too advanced a technical nature for some of the readers, but knowing that it will be valued by them at some future time, if not now, they have attempted to keep the scientific standard of the publication a high one. What success their efforts have met with, it remains for the readers to decide, but the Editors wish it to be understood that the credit for the scientific value of the JOURNAL is due to the contributors, especially to the members of

the Sibley Faculty and the advanced students of the College. They have been found to be always ready and willing to contribute generously to its pages, and, needless to say, their contributions have always been valuable. The Editors desire to extend to them their hearty thanks for this co operation and also to wish every success to the incoming Board, and to prophesy for the succeeding volume the merited success that the SIBLEY JOURNAL is sure to attain at all times.

THE List of Candidates for Fellowships and Scholarships for 1894–5 has been printed, and the selection of the twenty-three "fellows" and sixteen "scholars" has been made by the Faculty. Out of a total of the hundred and thirty or more candidates, an unusually small proportion were in Engineering, and only seven in Mechanical Engineering. Of the latter two, Messrs. S. H. Barraclough (B. E. Univ. Sydney, N. S. W., '92) and C. E. Houghton (A. B. Stanford Univ., '93) were elected. Mr. E. H. Hooker (A. B. Univ. Roch., '91, C. E. Cornell, '94) was elected in Civil Engineering; Mr. Robert Mayhew (C. E. '94) was given a scholarship in the same department; and the others of the forty appointments were distributed with an interesting irregularity to various other departments of the University. Architecture obtained one, Mr. W. E. Austin (Cornell, B. S., '94); Physics obtained one fellow and one scholar; Chemistry secured one fellow and one scholar; Entomology obtained one fellow; Geology secured one; Horticulture one; Mathematics one, and a scholar; English a fellow and a scholar; the Romance Languages a fellow; German, nothing; Classics two fellows and two scholars; Political Science and Economics three fellows; Physiology, etc., one scholar; History three fellows; Philosophy three fellows and six scholars. No department has too many; it is simply unfortunate that all cannot have as many as they can fill with able men. Nothing gives so much reputation, so high a standing, to a college as the work in research of this class of men. The expenditures in fellowships and scholarships are sure to come back in gain in fame, and numbers of undergraduates, consequent upon their presence. Sibley College, with its various branches of advanced work and its full third of the University attendance is entitled, numerically, to six fellows and five scholars and could profitably employ twenty of each class. In the course of its history, it has often had none, has rarely had two fellows, and is now, for the first time, assured of even that number. Here is one of the "Opportunities of a Great Technical College" and its friends.

CRANK SHAFTS.

—The Third Annual Commencement of Stanford University occurred May 30th, and forty-seven A.B.s, 12 A.M.s and one Ph. D. were graduated. Among the former were two in civil engineering and three in mechanical engineering; one of whom was in electrical engineering. One engineer also received his advanced degree. The Ph.D. is our colleague, George H. Ashley (Cornell M.E. '90) who has made a specialty of Natural History recently and settled at Palo Alto with another ex Cornellian, Professor Branner, as his Nestor. Professor Branner, on this occasion, gave the Commencement Address.

—Much interest has been directed, of late, to the subject of the electrotytic action of the return circuits of electric railways upon underground gas and water pipes. The public is indebted to Mr. I. H. Farnham and to Mr. J. H. Vail for interesting and valuable papers on the subject. They both concluded that much serious damage had accrued and was still accruing to underground pipes, lead-covered cables, etc., from this source. Mr. Farnham conducted an interesting experiment, by burying some cable and subjecting it to the action of an electric current, which proved that it was to electricity that we must look as the cause of this trouble. It was found in Boston that the water and gas pipes entering buildings were often at a considerable difference of potential, and it is said that in one case a man was found who was obtaining 25 amperes current at 8 volts pressure by simply twisting wires around two neighboring waterpipes.

—The U. S. Board of Supervising Inspectors of Steamboats have recently issued their annual report. They have been considering the forms of standard test-piece for boiler-plate. They specifically state that they adhere, *for iron plate* to the elsewhere obsolete form of test-piece, with its rounded score at the middle of a straight length; but they have finally concluded to adopt the now universally accepted form *for steel only*—a straight length of metal between two wider heads. The straight middle portion is to have a length equal to the section in square inches multiplied by eight. Thus, where an inch wide and a quarter thick, the length between heads will be only two inches. For half-inch plate, it will be four inches, and the metal must be an inch thick to give the part exposed to stretch, the now common and standard length of eight inches. The practice of this Board

has always, in this respect, been at variance with that of the leaders in engineering of modern times; and they seem still to cling to the traditions of an obsolete practice.

—It is now stated that the Government Commission, appointed to investigate frauds in armour plate supplied the United States, will recommend that "in future, mechanical engineers and not sailors be selected to inspect Government materials." Hitherto, the inspectors have been young sailors, not trained mechanical engineers. One of these young inspectors once called upon another officer, now a member of the Sibley College Faculty, and sought a "full explanation of the meaning and theory of what is called torsion;" and this long after his assignment to duty as an inspector, and after he had been engaged on some very important work. *The American Machinist* says "It is an anomalous condition of affairs which puts in the hands of soldiers the conduct of important mechanical operations." . . . . "This is a country much devoted to mechanical pursuits. It is a pity we cannot arrange to give our mechanics charge of public mechanical work." . . . . "Let shoemaking be done by shoemakers; let battles be fought by soldiers; let guns and other machinery be built by machinists, working under the direction of men who are also machinists."

—The Eighth Report of the U. S. Commissioner of Labor, at Washington has lately been distributed. It contains a large amount of valuable information relating to Industrial Education, especially as practiced in Europe. It is over a year since it was sent in manuscript to the President and it is thus somewhat behind time; it is exceedingly incomplete and unsymmetrical, even more so in regard to work in progress in the United States than abroad; it is somewhat "scrappy"; but the report contains, nevertheless, six hundred octavo pages of interesting and valuable information that every one concerned in any way with technical education will desire to add to his library. Curiously enough, the Commissioner seems to have been unable to obtain any information suggesting the existence of Cornell University or any knowledge of Sibley College. The work of a few other universities, and the slightest of information about smaller schools of engineering, constitute the contribution made in this report to the literature of this branch of the subject relating to the United States. It is one of the curiosities of literature that the most successful and extensive of the Land Grant Colleges should not find place here, and that the most complete, the largest, and the best equipped

school of mechanical engineering in the country or, perhaps, in the world, of its class, should have escaped the view of the one officer of the United States whose business it is to report upon them in this instance.

—According to the *Providence Journal* the details of the reorganization of a Corliss Steam Engine Co., are made public. All the property and patents now in force have been sold by the heirs of Mr. Corliss, and work will be resumed in all the departments. Over 1,000 men can be employed, and engines, condensing, non-condensing, single or in pairs, compound and triple expansion, will be built in sizes from 50 to 3,000 horse power. The Corliss boiler will be manufactured, and repair work will be given attention, as the company has the drawings, records and patterns of the engines built since 1849, when the plant was established by Mr. Corliss. The directors are well known representatives of New England industrial enterprises. The officers are: D. M. Thompson, president and treasurer; Stephen A. Jenks, vice-president; William B. Sherman, secretary; Charles E. Giles, agent, and Luther H. Wattles, superintendent. Mr. Thompson is a well-known mechanical engineer and has an excellent record as the manager of the numerous mills owned by B. B. & R. Knight. His entire time will be given to the manufacture of the Corliss engine as developed at the original works. It will afford great pleasure to all members of the engineering profession to know that this famous establishment is not to decay, and that this monument to the great inventor and all that he left behind will now be preserved, as he would have wished, and that something more than a name will still be preserved.

—Interesting lectures were given to Sibley College men in the afternoon and evening of June 8, on Ironclads, Ordinance and Armor, by Capt. W. H. Jaques, formerly of the U. S. Navy, late of the Bethlehem Iron Works, and one of the firm of Lee & Jaques, consulting engineers of New York City. The lantern was freely employed and a splendid series of illustrations of methods of manufacture, of structure, and of tests and results was presented to a very large and thoroughly appreciative audience. *Apropos* of which, it is announced that our government will lay down no new ships at present, but our nearest neighbors are to have greatly increased protection, thus: "The English Admiralty are either now constructing or will soon lay down a large number of warships, in accordance with their new naval program. There are in the number nine battleships of 14,900 tons displace-

ment and 13,000 indicated horse-power, bearing the names Jupiter, Mars, Majestic, Prince George, Caesar, Magnificent, Illustrious, Victorious and Hannibal. Two cruisers. the largest, fastest and most powerful ones ever designed, of 14,200 tons displacement and 25,000 horse-power, bear the sounding names of the Powerful and Terrible. Nine cruisers of 5,600 tons and 9,600 horse-power come next, bearing the names Venus, Diana, Dido, Iris, Juno, Doris, Eclipse, Minerva and Tàlbot. A 12,350 ton battleship, and two 4,360 ton cruisers are also on the list, together with 12 destroyers and three torpedo gun vessels. Four destroyers of the Havock design are also nearing completion, and 23 others are in hand in private yards. It is worth noting that the vast expenditure represented by this part of the new naval programme, upwards of $65,000,000, was required in consequence of the naval scare of last fall.—*Providence Journal.*

PERSONALS.

'88.

John M. Taylor, after graduating, returned to the University for two years advanced work in '91 and '92. He is now superintendent of drawing in the public schools of Waterburry, Conn. He is the vice president of the Naugatuck Valley Teacher's Association.

'90.

J. C. Ramage has been similarly employed in Baltimore, Md.

L. L. Bentley has, since graduation, been employed by the B. & O. Railroad, in their department of inspection and testing of materials of construction, at Baltimore, Md., and Pittsburg, Pa.

'91.

A. T. Kelsey, M. E., was married May 9, to Miss Jennie Updike of Waterburg, N. Y.

A. Louis Kuehmsted, after graduation, completed the expert course with the T.-H. company at Lynn in ten months, and was, during that time, frequently sent out on installation and repair work. Subsequently for a short time, he did similar work for the Mather Electric Co. During the college year of '92–'93 he was Professor of Electrical Engineering at the University of Illinois and graduated its first class in this profession. In July '93 he returned to Ithaca as Electrical Engineer of the Ithaca Street Rail-

way and the Brush-Swan Electric Light Plant. In this capacity he has had profitable and successful experience in the development, and management of water power.

'92.

Lyle Cruikshank is with the Hazelton Boiler works 716 E 13th St. N. Y.

Geo. H. Davis is the right hand man of J. H. Beckford, consulting engineer, Salem, Mass.

F. Raymond 3d, is a valued employee of the Columbia Incandescent Lamp Co., St. Louis, Mo.

Fred B. Corey, was married to Miss Caroline L. Heberd, Cornell, '93, on May 23, at Homer. N. Y.

A. B. Clemens now occupies a responsible position with the Pond Machine Works, Plainfield, N. J.

The SIBLEY JOURNAL desires to say that it was misinformed in regard to Mr. Geo. W. Bacon. Ford and Bacon are designing and constructing engineers specializing in power transmission, and are not in the electrical supply business.

Charles F. Whittemore, the inventor of the non-infringing incandescent lamp, who for the last two years has been connected with the Davis Electrical Works of Springfield, as their superintendent, has accepted an offer to assume charge of a large New York electrical concern recently formed. He assumed his new position on April 28, and his marked ability for his profession has won for him many friends who wish him success in his new field.

Bertrand P. Rowe shortly after graduation accepted a position with the Short Electric Railway Co. at Cleveland, O., where he was soon offered the position of superintendant of the Trenton Passenger Ry. Co., which he accepted. Subsequently, tempted by offers from the General Electric Co., he did them good service in New York, Brooklyn and vicinity. Being interested in electrolysis as a means of extracting the precious metals from low grade ores he spent several weeks in the summer of '93 in experimental work along that line at Cornell, and succeeded in developing a process more economical than any previously known, in that, instead of the solution "fouling" with use it actually gained cyanide. The process is patented in Mexico, and pending in the U. S. Mr. Rowe and wife are now at La Colorado Torres, Sonora, Mexico, where he has entire charge of the mines and is applying his invention.

'93.

Walter L. Eastman is with the Western Electric Co., in the Switch Board Dep't, of their New York Works.

Geo. E. Turner represents the same company in Central America, where he has charge of the telephone station.

F. L. Hutchinson has been with the Newark factory of the Westinghouse E. & M. Co. since graduation. He has found the work hard but pleasant, and has attended to his duties so well that he has found rapid advancement,notwithstanding the dull times.

'94.

L. S. Louer, formerly business manager of the SIBLEY JOURNAL, now holds a good position in Chicago, with the Buffalo Forge Co.

A RÉSUMÉ OF LOCAL EVENTS DURING THE SPRING TERM, 1894.

The past term has been filled, as spring terms usually are, with many events of interest to the student body and to the alumni, for whom this series of articles has been especially written.

Perhaps the first questions asked upon the return from the spring vacation are in regard to the crews and the baseball team. During the ten days of recess but little active work had been done in athletics, because of the rain and cold which had prevailed for the greater part of the time. The crew outlook was bright, and throughout the term the 'varsity has had the full confidence of the students. Should our long record of victories be broken by the result of this week's contest on the Delaware, we shall at least have the satisfaction of knowing that it has occurred through no lack of faithfulness in training. Two freshman crews were maintained until nearly June first, when it was thought best to disband the "first" crew, as no important race could be arranged. The second crew had proved itself very fast, however, and a race has been arranged for it with the Dauntless Club, of New York, to be rowed on Cayuga Lake.

A new departure in navy matters, was the establishment of a crew from the Cascadilla School. The venture has been a success, the youngsters proving themselves quite speedy, and there is no doubt but that hereafter the Cascadilla crew will become an important factor in Cornell aquatics.

The baseball outlook was good, and the expectations of the University have been more than realized in the excellent work of the team. The only weak spot has been in the pitching department, several games having been lost through inability to control the ball. The most exciting contest of the season on the home

grounds was the game with Pennsylvania on May fifth. The result was a victory for Cornell by the score of 13 to 10. The enthusiasm during and after the game reached a high pitch. The work of the team has been uniformly good, and has ably seconded last year's nine in placing Cornell in the front rank in this branch of athletics

General athletics has occupied a more prominent position in the thoughts of the student body than ever before. In the inter-collegiate meet at Berkeley Oval, Cornell gained five points, securing second in the two mile bicycle and the high jump, and third in the hammer throw. This is our best record so far, but the chances for next year seem bright.

The lacrosse management has been very unfortunate in its choice of dates for games, and most of them were played in a driving rain and to empty stands. The playing has been good and reflects credit upon the team. Johns Hopkins and the Onondaga Indians were easily defeated, but the game with Stevens Institute resulted in a victory for the latter.

One of the most interesting events of the term was the U. of P.–Cornell debate, which took place at the armory in the latter part of April. The contest was very close and the result was difficult to predict. The decision of the judges gave the victory to the visitors, sixty-six points having been scored by Pennsylvania against sixty-five for Cornell.

The '86 Memorial Contest claimed the usual amount of interest from the university, and while it was not as closely contested as in some previous years, the winner earned for himself a high place among Cornell's speakers.

The Senior Banquet proved to be a very enjoyable affair and the class of '94 is to be congratulated for having helped establish a precedent, which it is to be hoped will be followed hereafter—that of doing away entirely with the disgraceful scenes, which in former years were looked upon as necessary accompaniments of this event.

The appearance of the new *Cornellian* was hailed with the customary pleasure, and it seems to be the general verdict that '95 has produced an annual superior in many respects to its predecessors. Both literary and artistic matter are excellent.

The last few weeks of the term have been taken up with preparations for Commencement. The elections to Sigma Xi and Phi Beta Kappa, have been announced, fifteen seniors and twenty-two graduate students were honored by the former society, eight seniors and three juniors by the latter.